

Protecting Critical Ecosystems: Current EPA Regional Activities and Future Agency Opportunities

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I. Introduction

Research in both landscape ecology and conservation biology makes clear that habitat loss and fragmentation are the primary threats to biodiversity and ecosystem function (Wilcox and Murphy 1985; Harris and Silva-Lopez 1992; Forman 1995; Wilcove et al. 1998). As land is converted to intensive uses, landscapes become less capable of supporting wildlife, filtering water, abating floods, cleaning air, and providing a variety of other benefits characteristic of functional ecosystems (Daily 1997; Pimentel et al. 2000). In response, an important application of landscape ecology has been the development of regional-scale conservation analysis and planning. Regional-scale assessments are needed to understand relationships between ecosystems and to better integrate protection and management efforts (Harris 1984; Forman 1995; Turner et al. 1995; Harris et al. 1996a). In particular, the identification of critical areas for protecting various ecosystem functions (e.g., critical ecosystems) is essential for conserving natural resources and minimizing the degradation of ecological integrity caused by habitat fragmentation and other impacts (Noss and Harris 1986; Noss and Cooperrider 1994; Margules and Pressey 2000).

In the last two decades, advances in Geographic Information Systems (GIS) technology have led to significant improvements in the amount and quality of spatial data, analysis tools, and applications. These trends have allowed EPA Regions and other organizations to develop spatial data and analytical tools relevant to identifying critical ecosystems. Regional-scale identification of critical ecosystems provides an important foundation for proactive and efficient environmental protection. Therefore, the identification of critical ecosystems could be considered an essential step in EPA's mission to safeguard the environment for present and future generations. The identification of critical ecosystems can provide a coherent framework of protection and management priorities, and such a framework will allow EPA to target resources more efficiently and develop better policies and programs to protect environmental quality.

This report is a cooperative effort between the University of Florida, the EPA Office of Policy, Economics and Innovation, and EPA Regional offices (Regions 2, 4, 5, 6, 7, 8, and 10) to inventory current EPA Regional critical ecosystem assessments and other relevant projects to identify available data, methods, analytical tools, and gaps in available information. Various EPA Regions have recently conducted, or are developing, GIS applications to identify critical ecosystems or to assess environmental impacts. Although these projects do not always address the same objectives, they all incorporate GIS data and spatial tools relevant for identifying critical ecosystems. Other relevant studies and projects were also inventoried and included in the appendices to serve as an additional resource guide for data, tools, and methods. Based on this collective assessment of available resources, this report identifies the existing opportunities, important challenges and research priorities for enhancing future Regional critical ecosystems assessments.

The report is separated into methods, results, discussion, recommendations, and conclusion sections. The results include the descriptions of the Regional projects, commonalities and unique elements of the Regional projects, and how the projects address categories of analysis for critical ecosystem assessment. The discussion details the opportunities and challenges for enhancing future critical ecosystem assessments and

the types of analysis that can be conducted using available GIS data and tools. The recommendations include suggestions for data collection, new or expanded analyses, development of partnerships, and facilitating data and tool sharing. The appendices include more detailed descriptions of the Regional projects and additional information resources for conducting critical ecosystem assessments.

II. Methods

We collected the primary information for this report through collaboration with seven EPA Regional partners. Each Region provided the available materials describing completed or ongoing projects in their regions most relevant to regional-scale identification of critical ecosystems. Through this process the research team selected the following projects to be included:

Region 2—NEPAssist internet GIS tool for impact assessment

Region 4—Southeastern Ecological Framework (SEF)

Region 5—Critical Ecosystems Assessment Model (CrEAM)

Region 6—GIS Screening Tool (GISST)

Region 7—Synoptic assessment of wetland function model

Region 8—Environmental Monitoring and Resource (EMAP) water resources assessment

Region 10—Rapid Access INformation System (RAINS)

The categories of analysis from the EPA Science Advisory Board's (SAB) Framework for Assessing and Reporting on Ecological Condition (Young and Sanzone 2002) provide the framework for determining which ecological characteristics or functions were addressed by data and analyses in the Regional projects. We then developed descriptions of each Regional project which included the purpose of the project, GIS data used or made available, analytical techniques and spatial tools used, the GIS or other data created, and the SAB categories of analysis these data address. After developing the individual projects descriptions, we compared the Regional projects using tables to show how these projects addressed the SAB categories of analysis. We also identified the commonalities, unique components, and collective gaps of the Regional projects.

The research team also collected additional information through literature review and web searches to identify additional reports, projects, research results, databases, and other information relevant to the identification of critical ecosystems at regional scales. We used the Web of Science as the primary literature internet search engine to identify relevant published literature. EPA's websites include additional projects and other information that may address aspects of critical ecosystem assessment, and we used these to identify other relevant data and projects. We also conducted general web searches to find any additional information including work by other federal agencies or programs, NGO projects and reports, state assessments of critical ecosystems, GIS data websites, etc. This report includes this information in three appendices that incorporate additional summaries of projects or spatial tools relevant to identifying critical ecosystems and list relevant resources including citations, databases, and websites organized by SAB categories of analysis.

III. Results

The EPA Science Advisory Board (Young and Sanzone 2002) identified six “Essential Ecological Attributes” in the Framework for Assessing and Reporting on Ecological Condition. Three of the Attributes primarily address ecological patterns: landscape condition, biotic condition, and chemical/physical. The other three attributes are meant to address ecological processes: hydrology/geomorphology, ecological process, and natural disturbance. The Framework includes several “reporting categories” under each of the Attributes (Table 1). In this report, we use the hierarchy of SAB Attributes and their reporting categories as an analytical framework to organize data and analyses of the EPA Regional projects and collectively assess current strengths and gaps in existing efforts to identify critical ecosystems. The Regional project descriptions included in this section summarize the data, tools, and analyses included in each project. These descriptions are meant to provide a basic understanding of the data and analyses used and to serve as the basis for determining what is being addressed in current projects and what gaps exist.

Table 1. SAB Categories of Analysis used to organize Regional project descriptions

Essential Ecological Attributes					
Landscape Condition	Biotic Condition	Chemical or Physical Characteristics	Ecological Processes	Hydrology and Geomorphology	Natural Disturbance
Reporting Categories for each Essential Ecological Attribute					
Extent of ecological system or habitat type	Ecosystems and communities	Nutrient concentrations	Energy flow	Surface and groundwater flows	Frequency
Landscape composition	Species and populations	Trace inorganic and organic chemicals	Material flow	Dynamic structural characteristics	Intensity
Landscape pattern or structure	Organism condition	Other chemical parameters	Biotic processes	Sediment and material transport	Extent
		Physical parameters			Duration

A. Region 2 NEPAAssist Tool

U.S. Environmental Protection Agency. 2004. *NEPAAssist Web Site*. [Online] Retrieved May 27, 2004 at <https://epaqp.rtp.epa.gov/QuickPlace/nepassist/main.nsf/>.

The U.S. EPA Region 2 is developing a tool, NEPAAssist, which is a web-based application that facilitates the environmental review process and project planning. NEPAAssist allows users to select a study area and then indicates various features within or near the study area relevant to environmental impact including ecological features, managed lands, existing environmental stressors, and socioeconomic data.

1. Application Description

NEPAAssist incorporates data from GIS servers within EPA and other servers on the internet. The application provides information on a project's potential environmental impacts and offers a tool that allows automatic requests for review to be sent to the EPA. Users may select a study area within the region by ZIP code, city/county and state, Hydrologic Unit Code (HUC), or latitude/longitude. NEPAAssist then identifies features relevant to environmental impact assessment within or near the study area including Superfund sites, toxic releases, water dischargers, air emissions, listed species, wetlands, and hazardous waste; places such as schools, churches, and hospitals; highways and streets; water features including impaired water bodies and streams; and political boundaries. NEPAAssist is currently available for New York and New Jersey. Expansion of coverage to other parts of the U.S. will occur in the future.

2. Summary of the Region 2 NEPAAssist

NEPAAssist is intended to be a web-based, user-friendly environmental impact screening application. NEPAAssist incorporates nationally-available GIS data and potentially other GIS data sources that are relevant to regional-scale critical ecosystems assessment. Examples include:

- 1) American Heritage Rivers
- 2) Wild and Scenic Rivers
- 3) Drinking water intake points
- 4) Sole source aquifers
- 5) Impaired Streams and water bodies
- 6) Toxic releases
- 7) Air quality non-attainment areas
- 8) Wetlands
- 9) FEMA flood protection areas
- 10) Listed species habitat
- 11) Conservation lands including federal, state, and local parks
- 12) National Estuary Program areas
- 13) State designated environmentally sensitive area (for New Jersey in the existing application)
- 14) Hazardous waste sites

These data can be used in critical ecosystem assessments to identify priority areas for protecting biodiversity and ecosystem services or areas where threat abatement or mitigation is needed to reduce the impact of various stressors. These data can address various SAB categories of analysis including Landscape Condition, Biotic Condition, Chemical and Physical Characteristics, and Hydrology and Geomorphology. In the future NEPAssist may include more information on natural communities and focal species from NatureServe and their member state Natural Heritage programs. Such data are a high priority for improving future assessments of critical ecosystems.

B. Region 4 Southeastern Ecological Framework (SEF)

Carr, M. H., T. S. Hootor, C. Goodison, P. D. Zwick, J. Green, P. Hernandez, C. McCain, K. Whitney, and J. Teisinger. 2002. Final report: Southeastern Ecological Framework. Environmental Protection Agency Region 4, Atlanta, Georgia.

The Southeastern Ecological Framework (SEF) project was a cooperative effort between EPA Region 4 and the University of Florida to identify critical ecosystems within the Region. The SEF modeling was primarily focused on large, connected landscapes most important for conserving biodiversity and ecosystem services although other areas of ecological significance were also identified. The assessment included three major processes and GIS data products:

- 1) Various data layers indicating areas of ecological significance that served as the primary “building blocks” for the Southeastern Ecological Framework;
- 2) The SEF, which incorporates large connected areas of ecological priority across the region; and
- 3) An index-based modeling process to prioritize the SEF and identify additional ecological priority areas within the Region.

The SEF assessment provides a foundation for the adoption and implementation of effective and efficient conservation measures to minimize environmental degradation and protect important ecosystem services.

The SEF is a decision support tool created through a systematic landscape analysis process that can be replicated, enhanced with new data, and applied at different scales. The assessment used a combination of regionally consistent data and state specific information. The approach used (query-based identification of critical ecosystems) allowed the assessment team to take advantage of the detailed data available in some states that was not available for the entire region. The assessment used ArcInfo 7.x and primarily the raster functions in the GRID module.

1. Description of the Southeastern Ecological Framework Model

The delineation of the SEF included four major steps:

- 1) Inventory of available data and identification of Priority Ecological Areas (PEAs—the areas with the highest significance) and Significant Ecological Areas (SEAs—other areas of importance);
- 2) Delineation of larger areas of ecological significance called Hubs (e.g., contiguous areas 2,000 hectares or larger);
- 3) A connectivity assessment using least cost path analysis to identify opportunities for protecting landscape linkages and riparian buffers between Hubs; and
- 4) Combination of Hubs and linkages and spatial optimization of the combined network (filling gaps and smoothing edges).

a. Data Inventory and Identification of Priority and Significant Ecological Areas

Data came from national, regional, and state sources. All information was converted to raster data sets with 30 m cells. The National Land Cover Data (NLCD) was the base land cover data, which is based on Landsat imagery from the early 1990s. Certain analyses (such as neighborhood functions) required resampling grid data to 90

meters, which was the output resolution of the SEF. The research team used various data sets to delineate both Priority Ecological Areas (PEAs) and Significant Ecological Areas (SEAs). PEAs were the primary building blocks of the SEF whereas SEAs were one of the criteria used to determine suitability for connectivity (See Table 2). Except for significant riparian areas, SEAs represented lower significance thresholds for several of the PEA data layers (See Table 3). For both PEAs and SEAs, an area only had to meet at least one of the criterion to be selected. The model did not assign additional weight to areas that met more than one criterion. However, the research team identified overlap among PEA criteria and SEA criteria to serve as additional support for decision-making. PEAs and SEAs address various SAB categories of analysis including Landscape Condition, Biotic Condition, and Hydrology and Geomorphology (See Table 27, Table 28, and Table 30).

Table 2. Criteria for selecting Priority Ecological Areas for the Region 4 Southeastern Ecological Framework

Data layer	Priority Area Criterion	States in which criterion used
Areas of high habitat diversity	Index of habitat diversity identifying areas with 5 or 6 different habitat types within a 90-meter pixel 27x27 (5.9 sq. km) neighborhood using National Land Cover Data (NLCD).	All states
Significant natural edge habitat	Identifies areas that incorporate both significant natural open habitat and forest areas using NLCD.	All states
Wetlands	As defined by the overlap of wetlands identified in both NLCD and wetlands in USGS 1:100,000 hydrology data or wetlands in LUDA data (USGS land use/land cover data).	All states
Areas with significant longleaf pine stands	Mature longleaf pine forests from the Forest Areas Inventory Dataset. Longleaf pine stands are defined as stands that are at least 50 years old.	All applicable states
Old-growth forest stands	Old growth stands from the Forest Areas Inventory Dataset. Old growth stands are defined as stands that are at least 100 years old.	All states
Potential black bear habitat	NLCD forest, not within 0.8 kilometers of Class 1 roads, road density of less than 2 miles per sq. mile AND greater than or equal to 4000 hectares within 100 kilometers of occupied bear habitat.	All states
Existing public conservation lands & private preserves (e.g., Audubon, TNC)	All available existing conservation lands data within region 4, obtained from both state and regional sources	All states
Lands identified as part of the Coastal Barrier Resources Act	Undeveloped Coastal Barrier Areas (COBRA) as identified using the Federal Emergency Management Agency's Flood Insurance Rate Maps (FIRMs).	All states
Roadless areas	Areas 2000 hectares or larger with no roads (excluding large water bodies) of any kind based on 1990 TIGER roads	All states
Areas with high stream start reach densities	Defined as areas in the top 10% in stream start reach densities in the region with forested cover.	All states

Table 2 continued. Criteria for selecting Priority Ecological Areas for the Southeastern Ecological Framework

Data layer	Priority Area Criterion	States in which criterion used
National Estuarine Research Reserves, Shellfish Harvesting Waters, Wild and Scenic Rivers	All such designated aquatic ecosystems: All existing NERRs including a 1000 meter buffer, Wild and Scenic Rivers including a 1000 meter buffer, State Scenic Rivers (Florida only) including a 1000 meter buffer, approved and conditionally approved shellfish harvesting areas including 1000 meter buffer	All states
Element Occurrence data on rare species and communities	Buffered element occurrences of rare species and communities, and areas with high densities of rare species occurrences. Buffer distances were based on precision (indicating the distance in which the occurrence was observed) or species or community type. All buffered occurrences had a Global rarity of G1, G2 or G3 or had a State rarity ranking of S1/ S2 & were observed after 1975.	Florida, Georgia, Alabama
Proposed public conservation lands and easements	All such lands	Florida
Florida State Aquatic Preserves	All such designated aquatic features including a 1000 meter buffer	Florida
FNAI ^b Potential Natural Areas (PNAs)	Only PNAs within the top two priority levels (P1 or P2)	Florida
FNAI ^b Areas of Conservation Interest (ACIs)	All ACIs	Florida
FWC ^a Strategic Habitat Conservation Areas (SHCA)	All SHCAs	Florida
FWC ^a Vertebrate Species Hotspots	Based on FWC recommendations, all areas with values 10 and greater were designated priority ecological areas.	Florida
North Carolina Significant Natural Heritage Areas	Significant natural areas ranked either A or B in a statewide inventory.	North Carolina
North Carolina land trust priority areas	All areas identified in a workshop by North Carolina land trusts as priority conservation areas.	North Carolina
Coastal Fish Nursery Areas	Coastal waters important for the initial post-larval and juvenile development of young finfish and crustaceans in North Carolina, including a 1000-meter buffer.	North Carolina
Anadromous Fish Spawning Areas	Important anadromous fish spawning areas identified by the Division of Marine Fisheries, including a 1000-meter buffer.	North Carolina
Coastal Reserve Research Areas	State-owned coastal research areas that are completely protected, including a 1000-meter buffer.	North Carolina
Bump up criterion	All SEAs that overlap with significant riparian areas (see SEA criteria below)	All States

^a The Florida Fish and Wildlife Conservation Commission was previously named the Florida Game and Fresh Water Fish Commission.

^b Florida Natural Areas Inventory

Table 3. Criteria for selecting Significant Ecological Areas for the Southeastern Ecological Framework

Data layer	Priority Area Criterion	States in which criterion used
Areas of high habitat diversity	Areas that have 4 different habitat types within a 27x27 neighborhood using 90-meter pixels and NLCD landcover/landuse data.	All states
Potential black bear habitat	NLCD forest, not within 0.8 kilometers of Class 1 roads, road density of less than 2 miles per sq. mile and greater than or equal to 4000 hectares within 100-140 kilometers of occupied bear habitat.	All states
Roadless areas	Areas 1000 to 2000 hectares with no roads (excluding large water bodies) of any kind based on 1990 TIGER roads.	All states
Areas with high stream start reach densities	Defined as areas in the top 10% in stream start reach densities with forest cover within each ecoregion. EPA Region for is broken into various ecoregions (such as Southeastern Coastal Plain , Blue Ridge Mountains, etc.) based on geology, soils, climate, etc. These ecoregions were used as a unit of analysis for any factor that might vary significantly among ecoregions	All states
Significant riparian areas	NLCD wetlands adjacent to streams (within 180 meters), intact riparian vegetation adjacent to streams (delineated as pixels with 75% density of natural/semi-natural landcover in a 5x5 neighborhood within a 180m stream buffer), and 100-year FEMA floodplains (where data were available).	All states
FNAI ^b Potential Natural Areas (PNAs)	Priority level 3 through 5 areas from the Florida statewide inventory of potentially significant natural areas.	Florida
FWC ^a Vertebrate Species Hotspots	Based on FWC recommendations, areas supporting potential habitat for 6-9 focal vertebrate species.	Florida
North Carolina Significant Natural Heritage Areas	Significant natural areas ranked C in a statewide inventory.	North Carolina

^a The Florida Fish and Wildlife Conservation Commission was previously named the Florida Game and Fresh Water Fish Commission.

^b Florida Natural Areas Inventory

b. Delineation of Hubs

After PEA delineation, the research team deleted parts overlapping any areas of incompatible land use, high road density, or adjacent to intensive land uses to create a new dataset called Priority Ecological Areas after Exclusion (PEAX). The features deleted were: 1) all areas of intensive land use (intensive agriculture, urban, residential, commercial); 2) areas with road densities greater than or equal to 3 miles/mile² using all roads except jeep trails within the 1990 TIGER roads data set; 3) all landscape-scale areas dominated by 60% or greater of urban land uses; and 4) areas within 270 meters of blocks of urban land use greater or equal to 40 hectares. The exclusion steps including identification of areas with high road density, areas with high density of urban land uses, and areas adjacent to urban land uses address several SAB Landscape Condition reporting category (Table 27). Next, the SEF model delineated Hubs as all remaining PEAs after the exclusion process (the PEAX data layer) that were greater than, or equal

to, 2000 hectares. The 2000 hectare threshold was the same criterion used in the Florida Ecological Network model (Hector et al. 2000), which was based on extensive discussion at review meetings during its development. The model then spatially optimizes Hubs by filling internal gaps and smoothing outside edges gaps that contain compatible land uses.

c. Connectivity Analysis (Identification of Landscape Linkages and Riparian Buffers)

The connectivity assessment of the SEF model identified the best opportunities to connect appropriate Hubs. Linkage types included: 1) riparian linkages/buffers including all major river systems and coastal water bodies such as lagoons and connected estuaries; 2) upland linkages (used in mountain and plateau ecoregions); 3) General Hub-to-Hub linkages (to connect combination wetland-upland landscapes primarily in the Coastal Plain and Piedmont ecoregions). The research team developed an Arc Macro Language (AML) interface application in ESRI's Arc-Info to identify landscape linkages. The application incorporated the least cost path function, which can be used to identify the most suitable path between destinations based on an input cost surface that depicts the best landscape features for providing functional connections. Cost surfaces were created for each linkage type, where most appropriate landscape features for supporting a landscape linkage are given the lowest number (1) and the least suitable landscape features are assigned the highest number. After selecting a least cost path between Hubs, the research team delineated an appropriate width for each landscape linkage based on a minimum ratio of one unit of width for each ten units of length, contiguous appropriate land cover, and the landscape context around the linkage. The connectivity analysis addresses several SAB categories of analysis including Landscape Condition, Biotic Condition, and Hydrology and Geomorphology (See Table 27, Table 28, and Table 30).

d. Integration and Optimization of Framework Components

All the optimized Hubs and linkages formed the preliminary Southeastern Ecological Framework (SEF). Additional optimization resulted in the final SEF. The optimization included adding all PEAs after exclusion connected to the preliminary ecological framework; smoothing external edges; filling in areas containing suitable land use in narrow, linear gaps surrounded by the ecological framework; and filling in large internal gaps (less than or equal to 20,000 hectares) inside the ecological framework that contained suitable land uses (natural and semi-natural land cover).

2. Description of the Region 4 Prioritization Model

The purpose of the prioritization phase of the Southeastern Ecological Framework (SEF) Project was to identify areas within the framework that are higher priorities for conservation attention and protection. To accomplish this goal, the research team completed prioritization for four areas with the Region: the entire Region; within the boundaries of the SEF; all Hubs, and all Linkages. The prioritization of the entire region provided an opportunity to identify other areas of significance that may not be contained within the boundaries of the SEF. These analyses included data that were not available when the SEF was delineated and therefore provide additional opportunities to characterize and prioritize natural resources of significance region-wide. All region-wide prioritizations were done cell-by-cell (90 meter cells). The research team also "clipped" the Regional prioritizations to the SEF boundaries, which then showed priority areas

within the Framework. The Hub and Linkage prioritization summarize values for various criteria within each Hub or Linkage to identify relative priorities. For both the Hub and Regional prioritization analyses, the research team completed four categories of prioritization: Ecosystem Services, Biodiversity, Threats, and Recreation Potential. For Hubs there was an additional category: Hub Structure and Function. The research team prioritized Linkages using several different categories including Internal Structure, External Context, Width Analysis, and Hub Ranks. These categories rated linkages based on both their quality to serve as functional connectors and the significance of the Hubs that the linkages connect.

The SEF research team developed a ranking system with SUAs (Single Utility Assignments) and MUAs (Multiple Utility Assignments) to prioritize the SEF and its components (Hubs and Linkages). Using this method, the research team transformed various measures of priority into a common ranking system, from which multiple datasets can be compared and combined. This transformation involves reclassification of the data into a common interval scale of values, in this case, from 1 to 10. The research team created individual SUAs to address various aspects of each major prioritization category and then combined into one MUA for each of the major categories. The following sections briefly describe the prioritization categories and individual SUA indices.

a. Regional Prioritizations: Ecosystem Services

Ecosystem services are ecological processes and functions provided by natural and semi-natural areas that help sustain or enhance human life (Daily 1997). Primary ecosystem services include water and air protection and purification, flood and storm protection, and nutrient cycling (Table 4). Ecosystem Service prioritizations addressed SAB categories of analysis including Landscape Condition and Hydrology and Geomorphology (See Table 27 and Table 30).

Table 4. Ecosystem Service Single Utility Assignment (SUA) data layers

Data layer/SUA	Data Analysis/Rationale
Surficial Aquifer Areas Vulnerable to Pollution	U.S. Environmental Protection Agency (USEPA) and the National Water Well Association (NWWA) developed a method to map potential aquifer vulnerability to pollution. The analysis, referred to by the acronym DRASTIC, depicts areas which are more or less sensitive to land use changes which may affect ground water quality. This prioritization identifies areas in the region that are most vulnerable to surficial aquifer pollution, and hence most important for protecting ground water. A regional DRASTIC analysis, created by EPA Region 4 Planning & Analysis Branch, was used to delineate these vulnerable areas.
Size & Proximity to Wetlands	This analysis ranks wetlands and adjacent areas based on the size of the wetland and proximity to wetlands. Larger wetlands are typically more important for protecting water resources, as they retain the ability to filter larger volumes of water. Areas adjacent to wetlands are also important in moderating edge effects from neighboring intensive land uses, and offering additional filtering functions.

Table 4 continued. Ecosystem Service Single Utility Assignment (SUA) data layers

Surface Water Source Priorities	As a basic assessment of priority areas surrounding surface water sources for potable water, surface water intake points obtained from EPA were prioritized using population numbers associated with each surface water source point. Surface water intake points were buffered by 8 kilometers to indicate a potential area of influence around the intake point. Although this analysis was fairly coarse and more detailed analyses of watersheds important for drinking water are needed, it does indicate immediate areas of interest around surface water intake points prioritized by the size of the population served.
Ground Water Source Priorities	As a coarse assessment of priority buffer areas adjacent to ground water sources, ground water intake points obtained from EPA were prioritized by a proximity analysis, where buffer zones within 1.6 kilometers of an intake point were identified.
Major and Wild and Scenic River Buffers	Protection of riparian zones and additional upland buffers around rivers should be a high priority. To indicate the significance of areas adjacent to rivers within Region 4, lands adjacent to all major rivers and Wild and Scenic Rivers were identified.
Coastal Storm Protection Areas	Intact natural and semi-natural land cover within coastal areas can be important for minimizing storm damage related to coastal storms and especially hurricanes. As a surrogate for more specific FEMA data on coastal surge and flood areas, an analysis was created which identified all natural and semi-natural land cover in coastal areas (defined as land cover within HUCs intersecting the coastline) and prioritized these areas by size.
Shellfish Harvest Area Buffers	Approved coastal shellfish harvest areas must meet certain water quality standards to remain open to harvest. Although water quality within estuaries is dependent on all freshwater inflows, immediate buffer zones adjacent to estuaries harboring shellfish harvest waters are also important for maintaining water quality and hence were identified in this analysis.
Lands identified as part of the Coastal Barrier Resources Act	Undeveloped Coastal Barrier Areas (COBRA) as identified using the Federal Emergency Management Agency's Flood Insurance Rate Maps (FIRMs).

b. Regional Prioritizations: Biodiversity

The included biodiversity prioritizations identify areas important for protecting intact landscapes, natural communities, and species that address SAB categories of analysis including Landscape Condition and Biotic Condition (See Table 27 and Table 28). This includes information on areas most important for conserving functional ecological processes, the most species of conservation significance, and areas that are most likely to support viable opportunities to conserve biodiversity (Table 5).

Table 5. Biodiversity Single Utility Assignment (SUA) data layers

Data layer/SUA	Data Analysis/Rationale
Conservation Lands Size Classes and Proximity	In this analysis, existing conservation lands and adjacent areas were prioritized based on both the size of the existing conservation area and proximity to conservation areas. Existing public conservation lands and private preserves are focal areas for efforts to conserve biological diversity in most regions. The theory and practice of reserve design for conserving biodiversity demonstrate that larger conservation areas will often have a better opportunity to maintain intact ecosystems with functional processes and viable populations (Harris 1984; Noss and Harris 1986; Noss and Cooperrider 1994; Meffe and Carroll 1997). In addition, areas adjacent to existing public conservation lands can provide functional buffers for conservation lands, provide additional habitat for species of conservation interest, especially wide-ranging species, or can provide corridors or landscape linkages connecting existing conservation areas.
Interior Forests	In this analysis forest blocks not potentially disturbed by intensive land uses or roads were identified and then prioritized based on the size of the forest interior blocks. Interior forests are critical for conserving forest interior species and other forest dependent species including species that require large blocks of intact forest. Interior forests can be defined as forested lands that are sufficiently buffered from external effects or negative edge effects to provide intact forest habitat with interior conditions that are not edge-influenced.
Old Growth and Significant Longleaf Pine Forest Stands	Old growth forest and significant longleaf pine stands were identified using Forest Inventory Assessment (FIA) data as part of the Priority Ecological Area analysis for the Southeastern Ecological Framework.
Imperiled Species Priority Areas	As part of the book, Precious Heritage: the Status of Biodiversity in the United States, the Association for Biodiversity Information and The Nature Conservancy developed several analyses directly relevant to prioritizing areas based on their potential significance for conserving biodiversity (Stein et al. 2000). Their imperiled species analysis used the Environmental Protection Agency's EMAP hexagons (648.7 square kilometers) as a base unit to summarize the distribution of imperiled species across the United States. The prioritization analysis was created by prioritizing areas based on the potential number of imperiled species found in each area.

Table 5 continued. Biodiversity Single Utility Assignment (SUA) data layers

Listed Species Priority Areas	As part of the book, Precious Heritage: the Status of Biodiversity in the United States, the Association for Biodiversity Information and The Nature Conservancy developed several analyses directly relevant to prioritizing areas based on their potential significance for conserving biodiversity (Stein et al. 2000). Their analysis of federally listed species used the Environmental Protection Agency's EMAP hexagons (648.7 square kilometers) as a base unit to summarize the occurrence of listed species across the United States. The prioritization analysis was created by prioritizing areas based on the potential number of listed species found in each area.
At-Risk Aquatic Species by Watersheds (HUCs)	As part of the book, Precious Heritage: the Status of Biodiversity in the United States, the Association for Biodiversity Information and The Nature Conservancy developed several analyses directly relevant to prioritizing areas based on their potential significance for conserving biodiversity (Stein et al. 2000). The analysis of aquatic biodiversity was based on assessing the number of G1, G2, G3 aquatic species (fish and mussels only) found within watersheds represented by the U.S. Geologic Survey's eight digit Hydrologic Cataloguing Unit (HUC). The prioritization analysis was created by prioritizing areas based on the potential number of at-risk aquatic species found in each area.
Critical Watersheds for Aquatic Biodiversity	As part of the book, Precious Heritage: the Status of Biodiversity in the United States, the Association for Biodiversity Information and The Nature Conservancy developed several analyses directly relevant to prioritizing areas based on their potential significance for conserving biodiversity (Stein et al. 2000). The critical watersheds analysis identified all of the watersheds (based on eight digits HUCs) needed to contain all fish and mussels species found in the Natural Heritage database. All such watersheds were given a high priority in this analysis.
Black Bear Habitat Suitability Analysis	This analysis creates a cumulative index of habitat suitability for Black Bears (<i>Ursus americanus</i>) in EPA's Region 4. The purpose of this analysis is to identify potentially significant habitat blocks and landscape linkages to promote long term viability of black bear within the Southeastern United States. Eleven individual analyses indicating relative significance for black bear habitat potential were combined: habitat types, core habitat, distance from core habitat, roadless areas, habitat diversity, land use intensity, distance from intensive land uses, distance from primary roads, conservation lands, road densities, and habitat patch sizes.
Size Classification of Priority Ecological Area after Exclusion	This prioritization ranked all PEAs based upon their size, where larger-sized PEAs received a higher rank. Since there is a direct relationship between patch size and species diversity (Forman and Godron 1986) and because larger patches are more likely to conserve viable populations and functional ecological processes (Meffe and Carroll 1997; Forman 1995), larger PEAs are considered higher priority.

c. Regional Prioritizations: Recreation Potential

In order to identify resource-based recreation opportunities, the research team evaluated the influence of urban areas, conservation lands, water based recreation and points of interest to identify areas with the most potential significance for providing natural resource-based recreation (Table 6).

Table 6. Recreation Potential Single Utility Assignment (SUA) data layers

Data layer/SUA	Data Analysis/Rationale
Influence of Urban Areas	The concept behind this analysis is that the demand for resource-based recreation services increases with increasing population. Urban hubs were used as a representation of populated areas with a regional influence. Cities within 4.8 kilometers of one another were considered to be part of a common urban hub. The population of a hub is the sum total of the population of the individual cities making up the hub. Hubs were divided into 10 classes based on population. A gravity model was developed for the ranked urban hubs with the mean population of each group used as the attraction or value for recreation potential.
Influence of Conservation Lands	This analysis related level of resource based recreational service provided by existing conservation lands to the potential for recreation. The size of the conservation land is used as a surrogate measure of the potential level of service. Conservation areas were divided into 10 classes based on area. A gravity model was developed for the ranked conservation areas with the mean area of each group used as the attraction or value for recreation potential.
Water Based Recreation	This analysis defines the level of recreational potential provided by the water-based amenities. Water bodies were divided into three individual groups based on their recreation potential. Coastal areas were given the highest recreational potential, with Wild and Scenic Rivers given the next highest and other rivers, lakes and streams given the lowest value for recreational potential. Coastal areas were highest due to the diversity of resources and the demonstrated attraction that most coastlines have for recreational interest. Wild and Scenic Rivers were separated from other inland water bodies and given the next highest rank because these areas may tend to attract more recreational attention given their status. A gravity model was developed for the ranked water features into ten classes.
Influence of Points of Interest	USGS Points of Interest are geographic locals that have an attraction because of their natural beauty and uniqueness, their recreational potential or their historical value and other factors. In this analysis only those points of interests involving a natural or historical aesthetic were used. These points of interest were then divided into three ranks based on their recreational potential. "Named" natural features such as springs, summits, and islands were ranked the highest; campgrounds, hiking trails, lookouts and other nature based passive recreation features were ranked next highest; and less passive nature based points of interest including city parks were ranked the lowest. A gravity model was developed for the ranked points of interest to rank areas into ten individual groups based on number and proximity of points of interest.

d. Regional Threats/Stressors Assessment

The Regional threats analysis incorporates two related analyses that assessed the threats from intensive land uses and roads that can both negatively affect ecological integrity of existing natural and semi-natural lands, and the likelihood that such natural, semi-natural and agricultural lands will be converted to residential or urban land uses (Table 7).

Table 7. Threat/Stressor Assessment data layers

Data layer/SUA	Data Analysis/Rationale
Context Analysis: Landscape Viability Index	The purpose of this analysis was to create an index of threats to ecological integrity based on the intensity and proximity of potential disturbances. The index was composed of four analyses: proximity to areas of intensive land uses, proximity to major roads (primary & secondary), road density, and density of intensive land uses. The resulting MUA is an index of areas ranked from 1-10, where one represents an area with poor landscape suitability for the maintenance of ecological integrity and ten represents an area with high landscape suitability.
Urban Growth Potential Model	The potential for future urban growth was modeled using a set of parameters that evaluates existing urban land uses and infrastructure (roads) as an indicator of future growth. The parameters used were: distance from roads; distance from urban areas; urban density at a small scale; and urban density at a large scale.

e. Hub Prioritizations

The research team prioritized Hubs to identify overlap of PEAs, to evaluate the types of priority areas contained within each Hub, and to analyze Hub shape and composition. There were five prioritization types used to evaluate Hubs: ecosystem services, biodiversity, recreation potential, threats, and Hub structure and function.

1) Hub Prioritizations: Ecosystem Services

These analyses ranked Hubs based on their value for providing specific ecosystem services especially regarding water resources (Table 8).

Table 8. Hub Prioritization Ecosystem Service data layers

Data layer/SUA	Data Analysis/Rationale
Number of Stream Start Reaches per Hub	This prioritization was used to rank Hubs based on the number of stream start reaches that exist within each of the Hubs. Stream start reaches can be important for significantly influencing water quality in watersheds downstream, so Hubs with high numbers of stream start reaches are more significant for protecting water quality than those with fewer start stream reaches.

Table 8 continued. Hub Prioritization Ecosystem Service data layers

Percent Wetlands per Hub	This prioritization was used to measure the amount of wetlands that exist within each of the Hubs, and Hubs with higher percentages of wetland receive higher ranks.
Spatial Mix of Wetlands and Uplands	This analysis identified Hubs with significant mixes of upland forests and forested or herbaceous wetlands. Hubs containing significant mixes of wetlands and uplands are more likely to have functional flooding and fire processes especially in the Southeastern Coastal Plain. Although this analysis was included within the ecosystem service section, such areas can also have important biodiversity value.
Surficial Aquifer Vulnerability to Pollution by Hub	For this analysis, the regional prioritization based on the EPA DRASTIC model of surficial aquifer vulnerability was summarized by Hub.
Size of & Proximity to Wetlands by Hub	For this analysis, the regional prioritization for size and proximity to wetlands was summarized by Hub.
Coastal Storm Protection Areas by Hub	For this analysis, the regional prioritization for coastal storm protection areas was summarized by Hub.
Major and Wild & Scenic Rivers by Hub	For this analysis, the regional prioritization for major and wild and scenic rivers was summarized by Hub.
Shellfish Harvesting Areas Buffer by Hub	For this analysis, the regional prioritization for shellfish harvesting areas was summarized by Hub.

2) Hub Prioritizations: Biodiversity

The following prioritizations identified Hubs most important for protecting biodiversity including intact landscapes, natural communities, and focal species (Table 9).

Table 9. Hub Prioritization Biodiversity data layers

Data layer/SUA	Data Analysis/Rationale
Topographic Diversity	This prioritization was used to rank Hubs based on the topographic diversity that exists within each of the Hubs. Hubs with greater topographic diversity are expected to have greater elevational gradients that may be significantly correlated with the potential to support biodiversity.
Size & Proximity to Conservation Lands	For this analysis, the regional prioritization for size and proximity to conservation lands was summarized by Hub.
Black Bear Habitat Suitability Analysis	For this analysis, the regional prioritization for black bear habitat suitability was summarized by Hub.
Interior Forests by Hub	For this analysis, the regional interior forests prioritization was summarized by Hub.
PEA Size Classification	For this analysis, the regional PEA size classification prioritization was summarized by Hub.
Imperiled Species Priorities by Hub	For this analysis, the regional prioritization for imperiled species was summarized by Hub.
Listed Species Priorities by Hub	For this analysis, the regional prioritization for listed species was summarized by Hub.
Aquatic Biodiversity	For this analysis, the regional prioritization for at-risk aquatic species was summarized by Hub.
Critical Watersheds for Aquatic Biodiversity	For this analysis, the regional prioritization for critical aquatic biodiversity watersheds was summarized by Hub.

3) Hub Prioritizations: Recreation Potential

The Regional analyses of recreation were summarized for Hubs by calculating the average index value for each Hub.

4) Hub Threats

The research team summarized the two Regional analyses, the Context Analysis and Urban Growth Potential, for Hubs by calculating the average index value for each Hub.

5) Hub Structure and Function

The goal of the Hub structure and function prioritizations was to evaluate Hubs based on their shape, size, and internal and external compositions. An optimal Hub is characterized by a low amount of edge habitat (low perimeter to area ratio), low internal fragmentation, high quality internal habitat, and surrounded by natural, semi-natural or generally low intensity land uses. Principles of landscape ecology guided the evaluation patch characteristics, such as composition, size, and shape, in relation to the patch's ability to support viable ecosystems or natural communities (Table 10).

Table 10. Hub Structure and Function data layers

Data layer/SUA	Data Analysis/Rationale
Internal Gaps / Hub Density	This analysis was used as measurement of the contiguity or density of each individual Hub. Hubs with contiguous areas and minimum gaps or holes offer more suitable habitat areas with less opportunity for disturbance by poor land uses that may occupy areas within the overall Hub.
Internal Context of Hubs: Percent PEA per Hub	This prioritization was used to measure the proportion of Priority Ecological Areas (after exclusion) that are contained within each Hub. Hubs, by definition are PEAs after exclusion that are contiguously 2000 hectares or greater. However, through the processes of Hub optimization and network optimization, other areas that are not PEAs, but are of suitable land use, are added to the core Hubs. This analysis gives a measure of how much area was added during the two optimization processes.
Internal Context of Hubs: Percent SEA per Hub	This prioritization was used to measure the proportion of Significant Ecological Areas (after exclusion) that are contained within each Hub. The range of percents for SEA per Hub varies more than PEAs because SEAs are not the primary component in the creation of Hubs.
Internal Context of Hubs: Land Use Context Index	Intensive land uses were excluded from Hubs during the exclusion process, however pockets of intensive land uses may be enclosed within and surrounded by Hubs and exert a negative influence on Hubs. This prioritization evaluates the influence of intensive land uses within Hubs.
External Context of Hubs: Land Use Context	This prioritization was used to measure the intensity of land uses adjacent to Hubs. Land use intensity is measured using the Land Use Context Index (see description above) within a 5 kilometer buffer of each Hub.
External Context of Hubs: PEAs	This prioritization was used to measure the amount of PEAs that exist within a 5 kilometer buffer of the Hubs.

Table 10 continued. Hub Structure and Function data layers

External Context of Hubs: SEAs	This prioritization was used to measure the amount of SEAs that exist within a 5 kilometer buffer of the Hubs.
Hub Total Area Index	This measure ranked Hubs based on their total area where larger Hubs receive higher ranks.
Hub Core Area Index	The purpose of this prioritization was to calculate the core or interior area for each Hub. Core areas are important because they are the most remote areas within the Hub and are least likely subjected to negative edge effects. Core area is defined as the area of the largest circle that fits within the Hub, also called the largest-circle-fit technique.
Hub Core Roadless Area Index	The purpose of this prioritization was not to identify any roadless area, but specifically core roadless areas with compact shapes and low amounts of edge. Core roadless areas are determined by calculating the largest circle that fits within a Hub that is not bisected by major roads (primary or secondary roads).
Perimeter of Circle to Perimeter of Patch (Hub) Ratio	The purpose of this prioritization was to analyze Hub shape as it compares to a circle. As stated in the description of the Hub Function & Structure Prioritizations, a circle is considered an ideal shape because it is the most compact shape with the least amount of edge. To compare Hub shape to that of a circle, the ratio of the perimeter of each Hub to the perimeter of a circle having the same area as the Hub was calculated.
Hub Corrected Perimeter to Area Ratio	The purpose of this prioritization was to compare Hub perimeter to Hub area. The basic premise here is that if two Hubs have the same area, the one with a smaller perimeter is more compact and has less edge, and is more desirable because it has more interior habitat area and is less susceptible to negative edge effects. However, because a simple perimeter-to-area ratio is dependent on size as well as perimeter, it is necessary to use an equation that corrects for variance caused by change in Hub size if such a ratio is to be a helpful indicator of Hub shape.
Amount of Roads Per Hub	This prioritization calculated the percentage of primary and secondary road cells per Hub, where Hubs with a less road crossings receiving higher ranks.

f. Linkage Prioritizations

Optimal linkages are characterized by a contiguous swath of land with adequate width and high quality habitat. To analyze habitat quality, width, and contiguity of Linkages, the research team conducted three prioritization types: Internal Context Analyses, External Context Analyses, and Width. In addition, a fourth prioritization ranked the linkages based upon the overall prioritization ranking of the Hubs that they connect. There were three types of Linkages: general, upland, and riparian, based upon the type of Hubs they connect, and each type was prioritized separately.

1) Linkage Prioritizations: Internal Context Analyses

To measure the habitat quality and potential functionality of linkages, the research team calculated the percentage of PEAX (Priority Ecological Areas after excluding unsuitable land uses) and SEAX (Significant Ecological Areas after excluding

unsuitable land uses) in each linkage. To measure the negative edge effects from roads and fragmentation, the percent of primary and secondary roads per linkage was calculated. Also, the research team evaluated the overall intensity of land uses within the linkages as a measure of land use quality within the linkages.

2) Linkage Prioritizations: External Context Analyses

The purpose of the external context analyses was to obtain a measure of the landscape context surrounding the linkages. Linkages surrounded by low intensity land uses, priority or significant ecological areas are less affected by negative edge effects and offer better opportunities for functional connectivity. In all three of these analyses, a one kilometer buffer served as the area of potential influence directly relevant for determining the contextual quality of the linkages based on a conservative estimate of the potential for edge effects and other types of landscape interactions (Forman 1995).

3) Linkage Prioritizations: Width Analyses

In addition to containing high quality habitat, an optimal linkage should also include a swath of contiguous land area with adequate width. Although there remains no exact determination of "how wide should a linkage be", conservation biologists generally accept the guideline "the wider, the better" (Noss 1987; Hunter 1990; Harris and Scheck 1991; Noss 1993; Harris et al. 1996b; Beier and Noss 1998). Functional widths will also be influenced by the context of the linkage, with the assumption that linkages surrounded by more intensive land uses will need to be wider. Length is also an important factor, and linkages should be wider as length increases, especially if the linkage is intended to support wide-ranging species such as black bear. The research team conducted a natural/semi-natural land cover density analysis and measured perimeter-to-area ratio to assess linkage contiguity and width. Because a simple perimeter-to-area ratio is dependent on size as well as perimeter, the research team used an equation that corrects for variance caused by change in size.

4) Linkage Prioritizations: Hub Ranks

The purpose of this prioritization was to rank linkages based upon the priority ranking of the Hubs which they connect. Linkages that provide connectivity between high priority Hubs should be of higher priority themselves, as linkages can potentially enhance the Hub's ability to support viable ecosystems and natural communities through exchange and movement of resources between Hubs. Therefore, the research team ranked Linkages based upon the overall rank of the Hubs that they connected.

3. Summary of the Region 4 Southeastern Ecological Framework Assessment

The Southeastern Ecological Framework Assessment had two major phases. The first phase included an inventory of available GIS data to identify areas of ecological significance across the region. Criteria for ecological significance included areas important for protecting biodiversity and ecosystem services such as water quality and flood abatement. The model then incorporated this information into a process to identify large, connected areas of ecological significance throughout Region 4. There were two major products:

- 1) The identification of Priority Ecological Areas (PEAs) and Significant Ecological Areas (SEAs--considered lower priority than PEAs) using various available national, regional, and state GIS data;
- 2) The Southeastern Ecological Framework, which incorporates PEAs, SEAs, and others compatible areas into a network of large Hubs and landscape linkages.

The Southeastern Ecological Framework represents the best, or most important, opportunities to protect large, connected landscapes in Region 4. One of the primary strengths of this approach is the emphasis on protecting large, connected landscapes, which are more likely to support viable populations of focal species and functional ecological processes. In addition, users of the SEF data can also identify smaller areas of significance, select particular focal areas, or specific types of ecological significance by using the PEA, SEA, Hub data. A particular issue with the delineation of the SEF is that in some cases data not available for all states within Region 4 were used in the modeling process. The strength of this approach is that it allows for incorporation of the best available data for identifying areas of ecological significance. In order to use the approach, it was necessary to rely on a query-based process where thresholds were set for each available data set to determine what areas would qualify for PEA or SEA status, and more areas may be identified as ecologically significant in states where more data are available. Since data availability and criteria used to delineate PEAs and SEAs could vary between states, an index-based or other statistical approach was not feasible. Therefore, these methods could reduce the consistency of the results across the region and could make it difficult to compare results across states.

The second phase of the Southeastern Ecological Framework (SEF) assessment was an index-based approach that prioritized areas within the SEF and identified additional areas of ecological significance. In this phase, the research team used only data available for the entire region to identify areas important for protecting biodiversity and a variety of ecosystem services. The modeling identified stressors to ecosystem integrity by assessing existing impacts from intensive development and the potential for future conversion to intensive development. The prioritization phase used several data sets that were not available during the delineation of the SEF, along with data used to delineate the SEF that was available for the entire region. This process established indices that were consistent for all of Region 4 and can be used to identify areas of ecological significance using various criteria both within the SEF and within the entire region.

One of the primary issues for both SEF phases and for other regional assessments of critical ecosystems is data availability. Available GIS data and tools continue to evolve rapidly, but more information is needed to better identify areas important for protecting intact or restorable landscapes, important natural communities and viable populations of focal species are needed to ensure that results of these assessments capture all areas of significance and can be prioritized to focus on the areas most important for maintaining biodiversity. The same is true for ecosystem services including more comprehensive assessments of areas needed to protect water and air resources. This will be discussed further in the discussion section below.

C. Region 5 Critical Ecosystems Assessment Model (CrEAM)

White, M. L., and C. G. Maurice. 2004. CrEAM: A Method to Predict Ecological Significance at the Landscape Level. Submitted to the Science Advisory Board. U.S. Environmental Protection Agency, Region 5, Chicago, IL, September 2004.

Perrecone, J.P., C.G. Maurice, and M.L. White. 2002. *Landscape Evaluation of Ecosystem Health Using Existing Data Sets*. Critical Ecosystems Team, U. S. Environmental Protection Agency, Region 5, Chicago, IL.

The Critical Ecosystems Team of EPA Region 5 created a GIS model to identify areas that have a high potential to be ecologically significant. The model, known as CrEAM (Critical Ecosystems Assessment Model), is currently undergoing peer review and validation. The Model is intended to identify critical ecosystems in order to focus protection and/or restoration efforts. All data was complete for all six states within EPA Region 5. All of the input data are also nationally available; therefore, a similar analysis could be conducted in other EPA Regions. All data manipulation was completed using ArcView 3.2 or ArcInfo 8.1.2.

1. Model Description

Land cover data, from the 1990 to 1992 National Land Cover Database (NLCD) was used as the base data layer. Because NLCD was used as a base reference, Region 5 collected other data that were as consistent with 1992 environmental conditions as possible. The NLCD was at a 30m² grid cell size, and results were summarized at a 300m² grid cell size. Region 5 used three primary criteria in the analysis:

- 1) Ecological diversity (populations, communities, and ecosystems),
- 2) Self sustainability, and
- 3) Occurrences of rare land cover types and rare species (see Figure 1).

Each grid cell in each data layer was given a score from 0 to 100 for each of the three criteria indicating that it had higher or lower diversity, was more sustainable or less sustainable, or that it represented more rarity or less rarity. The model combined the three composite layers to create a final composite, which gave each grid cell an “ecosystem score.” The ecosystem scores ranged from 23 to 253 and the average score was 139. The scores are meant to assist workload prioritization and other types of management decisions.

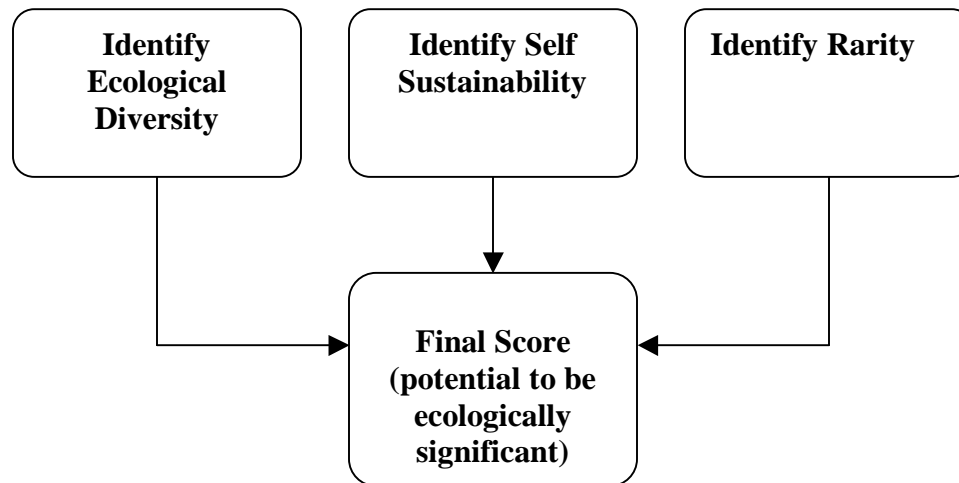


Figure 1. Modeling process of Region 5 Critical Ecosystems Assessment Model

a. Ecological Diversity

To address the criterion of ecological diversity, Region 5 used four data layers as indicators to produce a “diversity composite” layer and included land cover diversity by ecoregion, temperature and precipitation maxima by ecoregion, appropriateness of land cover, and contiguous sizes of undeveloped areas (Table 11). This criterion addresses the three reporting categories of the SAB Landscape Condition category of analysis (Table 27).

Table 11. Region 5 CrEAM Ecological Diversity data layers

Data layer	Data Analysis/Rationale
Land Cover Diversity By Ecoregion	The first data layer, indicating land cover diversity by ecoregion using the National Land Cover Dataset (NLCD), was calculated by using the Shannon-Weiner diversity index. The Analytical Tools Interface for Landscape Assessments (ATtILA) Version 3.0 landscape tool was used to calculate land cover richness and evenness. A higher Shannon index indicated a higher diversity, and a lower Shannon index indicated lower diversity.
Temperature and Precipitation Maxima By Ecoregion	The second data layer indicated temperature and precipitation maxima by ecoregion. Data from the Midwest Regional Climate Center (MRCC) was applied to Region 5 using 25 georegistered tie points. The georegistered tie points were overlain with the USECO coverage, available through the EPA Spatial Data Library System (ESDLS). The USECO coverage provides polygon coverage of Level III Omnerik Ecoregions. The area within each ecoregion with the highest average daily temperature and daily precipitation were identified and considered to indicate higher diversity.

Table 11 continued. Ecological Diversity data layers

Appropriateness Of Land Cover (using Kuchler)	The third data layer indicated appropriateness of land cover. To create this dataset, NLCD was compared with Kuchler Potential Natural Vegetation (PNV) to make a comparative measure of appropriateness of land cover. A 500-meter Digital Elevation Model, 4th Code Hydrologic Units, and Ecological Subregions were used to refine Kuchler's Potential Natural Vegetation (PNV) map to match terrain. Kuchler appropriate land cover was considered to be more sustainable and Kuchler inappropriate land cover was considered to be less sustainable.
Contiguous Sizes of Undeveloped Areas	The fourth data layer used to produce the diversity composite indicated contiguous sizes of undeveloped areas. Undeveloped Areas of nine hectares or larger were identified, based on the principle that larger, undeveloped areas favor diversity. The National Land Cover Dataset (NLCD) coverage and landcover classes were used to classify data as either developed or non-developed.

b. Self-sustainability--Fragmentation

Region 5 developed the second criterion used in the analysis, self sustainability, by combining twelve data layers to produce a “sustainability composite” layer. The model combined the data layers into two groupings of “fragmentation” or “stressors.” The five data layers included in the group indicating fragmentation were area/perimeter ratio, waterway impoundments per waterbody, road density, contiguous sizes of individual land cover types, and appropriateness of land cover (Table 12). For these data layers, larger area/perimeter, fewer impoundments, lower road density, larger contiguous area, and Kuchler appropriate land cover were considered to be more sustainable. Smaller area/perimeter, more impoundments, higher road density, smaller contiguous area, and Kuchler inappropriate land cover were considered less sustainable. These data address the SAB categories of analysis Landscape Condition and Hydrology and Geomorphology (See Tables 27 and Table 30).

Table 12. Self-sustainability--Fragmentation data layers

Data layer	Data Analysis/Rationale
Area/Perimeter Ratio	The data layer indicating area/perimeter ratio of contiguous land cover areas identified areas that had the "smoothest," or least irregular boundaries under the principle that these areas would have the least amount of “edge effect” and greatest self-sustainability. The NLCD classification schemes were used and only areas that were greater than or equal to nine hectares (ha) were identified and analyzed for their area/perimeter ratios.
Waterway Impoundments Per Waterbody	The second data layer indicated waterway impoundments per water body. All areas of open water that intersected with a 500-meter buffer surrounding each dam site were identified. The NLCD classifications open water, woody wetlands, and emergent herbaceous wetlands were classified as open water. Open water within 500-meter dam buffers was considered to be ecologically disturbed and the whole water body was identified as such.

Table 12 continued. Self-sustainability--Fragmentation data layers

Road Density	The third data layer indicated road density. Data indicating road presence and classification of roads was obtained from the 1990 U.S. Census Bureau TIGER/Line files. The road classifications primary, secondary, local and rural, and miscellaneous, were used. Road densities were calculated based on the road classifications' presumed width of disturbance effects described in the Environmental Protection Agency document Evaluation of Ecological Impacts from Highway Development (1994).
Contiguous Sizes Of Individual Land Cover Types	The fourth data layer indicated contiguous sizes of individual land cover types. The NLCD coverage and landcover classes were used to identify areas of similar land cover that were greater than or equal to nine hectares (ha). Larger contiguous areas of similar land cover were considered more sustainable.
Appropriateness Of Land Cover (using Kuchler)	The fifth data layer used to indicate fragmentation identified appropriateness of land cover. This layer was created by comparing NLCD with Kuchler Potential Natural Vegetation (PNV) to make a comparative measure of appropriateness of land cover. A 500-meter Digital Elevation Model, 4th Code Hydrologic Units, and Ecological Subregions were used to refine Kuchler's PNV map to match terrain. Kuchler appropriate land cover was considered to have a higher diversity and Kuchler inappropriate land cover was considered to have a lower diversity.

c. Self Sustainability--Stressors

The stressors grouping under the self sustainability criterion included the following data layers: airport noise, superfund NPL sites, hazardous waste cleanup sites, water quality (summary from BASINS model), air quality (from OPPT air risk model), waterway obstructions, and urban disturbance (Table 13). Areas considered to be more sustainable had land outside of airport buffer zone; land outside of NPL sites; land outside of RCRA site zone; low nitrogen, low sediment, and high oxygen availability; fewer exceedances of air quality thresholds; fewer dams per Hydrologic Unit Code (HUC); and land outside the developed buffer areas. Areas considered to be less sustainable had land within an airport buffer zone; land within NPL sites; land inside RCRA site zones; high nitrogen, high sediment; and low oxygen; more exceedances of air quality thresholds; more dams per HUC; and land within the developed buffer areas. The Stressors criteria address both the Chemical and Physical Characteristics and the Hydrology and Geomorphology SAB categories of analysis (See Table 29 and Table 30).

Table 13. Self-sustainability--Stressors data layers

Data layer	Data Analysis/Rationale
Airport Noise	The data layer indicating airport noise was created by using a buffer distance around airports. Various buffer distances were used to correspond with runway length, which was assumed to correlate with size of aircraft and noise disturbance.
Superfund NPL Sites	The second stressor data layer indicated superfund NPL sites. The U.S. EPA Region 5 Comprehensive Environmental Recovery, Compensation, and Liability Information System (CERCLIS) database was used to identify all un-owned sites where hazardous waste had been released and were in the formal clean up process during fiscal year 2000. Each site was assigned a 300-meter buffer zone.
Hazardous Waste Cleanup Sites (RCRA)	The third stressor data layer indicating, hazardous waste cleanup sites, was created by identifying owned RCRA Corrective Action Sites, which were in the formal clean up process during fiscal year 2000. Each site was assigned a 300-meter buffer zone.
Water Quality (BASINS Model Summary)	The fourth data layer of the stressor grouping indicated water quality and was created by using a 1990 - 1995 dataset that identifies ambient levels of the three categories of dissolved oxygen, total suspended solids, and total nitrogen (nitrates and nitrites) obtained through the U.S. EPA Storage and Retrieval(STORET) and Toxic Release Inventory (TRI) databases. The Better Assessment Science Integrating point and Nonpoint Sources (BASINS) model Version 3.0 ASSESS tool was used to identify threshold exceedances within the 8-digit HUC classification of watersheds in Region 5.
Air Quality (From OPPT Air Risk Model)	The OPPT air risk model output was used to indicate air quality in the fifth data layer used in the stressor grouping. The model uses modeled results of facility emissions for 85 chemicals and identified the areas that exceeded chronic, non-cancer thresholds for those chemicals.
Waterway Obstructions (Dams per HUC)	The data layer in the stressor grouping indicating waterway obstructions was calculated by measuring dam density per watershed. Watersheds were classified using the U.S. Geological Survey (USGS) National Mapping Division's 8-digit HUC classification system.
Urban Disturbance	The final data layer used in the stressor grouping indicated urban disturbance. NLCD was used to identify developed areas and a 300m buffer was placed around them. Any undeveloped cells that fell into the buffer zone were considered less sustainable.

d. Occurrences of Rare Land Cover Types and Rare Species

The third major criterion, occurrences of rare land cover types and rare species, was indicated by four data layers. The model combined these data layers to produce a “rarity composite” layer. The four data layers included land cover rarity by ecoregion, species rarity per 7.5 minute quad, number of rare species per 7.5 minute quad, and

number of rare taxa per 7.5 minute quad (Table 14). Areas were considered to exhibit more rarity if land cover type is very rare, species rarity had a Natural Heritage rating of G1 (which are species with very few documented occurrences), more rare species were observed, or more rare taxa were observed. Areas were considered to be less rare if land cover type is ubiquitous, species rarity had a Natural Heritage rating of G5 (species that are secure), fewer rare species were observed, or fewer rare taxa were observed. This criterion addresses the Biotic Condition SAB category of analysis (Table 28).

Table 14. Occurrences of Rare Land Cover Types And Rare Species data layers

Data layer	Data Analysis/Rationale
Land Cover Rarity by Ecoregion	The first data layer indicating rarity identified land cover rarity by ecoregion. The National Land Cover Data (NLCD) coverage of undeveloped land cover categories was overlain with a shape file containing Omernik Ecoregions and a frequency distribution of land cover type by ecoregion was tabulated.
Species Rarity Per 7.5 Minute Quad	The second data layer to indicate the rarity criterion was species rarity per 7.5 minute quad. The level of species rarity was indicated by the Global Natural Heritage ranking system created by The Nature Conservancy, which was applied to each 7.5 Minute Digital Orthophoto Quadrangle (DOQ) within U.S. EPA Region 5. Rankings of G1 through G5 were included in the analysis. A quad with the highest ranked observed species at G1 was given a higher score than one with the highest ranked observed species at G5.
Number Of Rare Species Per 7.5 Minute Quad	The third data layer included in the rarity composite layer indicated number of observations of rare species per 7.5 minute quad. The number of rare species within a given area was indicated by the Global Natural Heritage ranking system created by The Nature Conservancy, which was applied to each 7.5 Minute Digital Orthophoto Quadrangle (DOQ) within U.S. EPA Region 5. Rankings of G1 through G3 were included in the analysis.
Number Of Rare Taxa Per 7.5 Minute Quad	The fourth data layer included in the rarity composite layer indicated number of observed rare taxa per 7.5 minute quad. The number of broad taxonomic groups within a given area was indicated by the Global Natural Heritage ranking system created by The Nature Conservancy, which was applied to each 7.5 Minute Digital Orthophoto Quadrangle (DOQ) within U.S. EPA Region 5. Rankings of G1 through G3 were included in the analysis.

2. Summary of the Region 5 Critical Ecosystems Assessment Model (CrEAM)

The Region 5 Critical Ecosystems Assessment Model (CrEAM) is intended to identify areas of ecological significance (critical ecosystems) throughout Region 5. CrEAM combines individual indicators into major categories of ecological significance or stressors, which is similar to the prioritization phase of the Region 4 SEF project. Region 5 organized indices of ecological significance into three major categories:

- 1) Ecological diversity;
- 2) Self-sustainability; and
- 3) Land cover and species rarity

The ecological diversity criterion included indices addressing land cover diversity, potential climatic influences on diversity, land cover similarity to potential natural vegetation, and patch size/landscape intactness. The self-sustainability criterion included two major components:

- 1) Fragmentation, which addressed patch shape/core habitat; aquatic habitat fragmentation (impoundments); road densities; patch sizes of land cover types; and similarity to potential natural vegetation, and
- 2) Stressors which addressed disturbance from airports and urban land uses; major pollution sources, air and water quality, and aquatic habitat disturbance (dams).

The rarity criterion addressed land cover type rarity within each ecoregion, degree of species rarity, number of rare species, and number of rare taxonomic groups summarized by quad. Region 5 then combined these three primary indices to create one cumulative score of potential ecological significance throughout the Region.

All of the data used in creating these indices are either currently available nationally or, in the case of Natural Heritage quad summary data, could be obtained in other regions. All tools used to create the individual and combined indices are also readily available. Overall, the CrEAM process represents a concise and repeatable methodology that would be at least relatively easy to apply to other regions. However, as also discussed in the Region 4 summary, more GIS data and tools are needed, or results of other assessments could be used, to strengthen aspects of such regional-scale critical ecosystem assessments. In particular, more detailed information on biodiversity conservation needs would be helpful, including the availability of more precise rare natural community and species location data (versus quad summary data), habitat models of selected focal species, and, when feasible, viability assessments for selected focal species. In addition, more information is needed to conduct more detailed assessments of specific ecological services including the identification of areas needed to protect drinking water sources and other associated water and air quality issues.

D. Region 6 GIS Screening Tool (GISST)

U.S. Environmental Protection Agency. 2003. *GIS Screening Tool (GISST) User's Manual*. Environmental Protection Agency, Region 6. 44 pp. + 5 appendices.

EPA Region 6 has created a GIS system, the GIS Screening Tool (GISST), to provide a systematic approach for assessing individual and cumulative impacts to facilitate environmentally sound decisions. The system uses GIS coverages and applies a scoring structure to this data to serve as an environmental impact assessment decision support tool. There are six major criteria classes in the tool including water quality, ecological, air quality, socioeconomic, toxicity, and Concentrated Animal Feeding Operations (CAFO). Under each of these major criteria, individual data layers are created that rank areas on a scale of 1 to 5 to indicate level of environmental sensitivity. The system is designed so that it can be applied to nearly any program or project and criteria can be developed based on need and available data. The system may be applied at spatial scales ranging from local to regional. GISST is intended as a screening-level tool to indicate areas that may need additional study, but it is not intended to replace traditional risk assessment or field investigations. Advantages of GISST include the flexibility of the system to add new criteria at any time and the ability to apply GISST at varying scales for local to regional projects.

1. Model Description

The GISST system consists of criteria (environmental vulnerability and environmental impact criteria) and applies a scoring structure using available data sets and expert input (see Figure 2). There are three components to the GISST equation: environmental vulnerability, environmental impact, and area (of the watershed, project, etc.). The scoring structure/ranking system for each is 1 to 5 for each criterion with 1 indicating low environmental concern and 5 indicating high concern. Finalized criteria and provisional criteria may be included in the system. Finalized criteria have been peer-reviewed and used in one or more projects. Provisional criteria are in the process of being developed, peer reviewed, and finalized, or do not yet have a database to support their use. Impact and vulnerability finalized criteria included in the GISST system include the broad groups of water quality, ecological, air quality, socioeconomic, toxicity, and CAFO (concentrated animal feeding operations). These broad categories are comprised of a number of individual data layers as discussed below. However, since they are less applicable to the identification of critical ecosystems, the individual data layers for the Socioeconomic criterion and the CAFO criterion are simply listed.

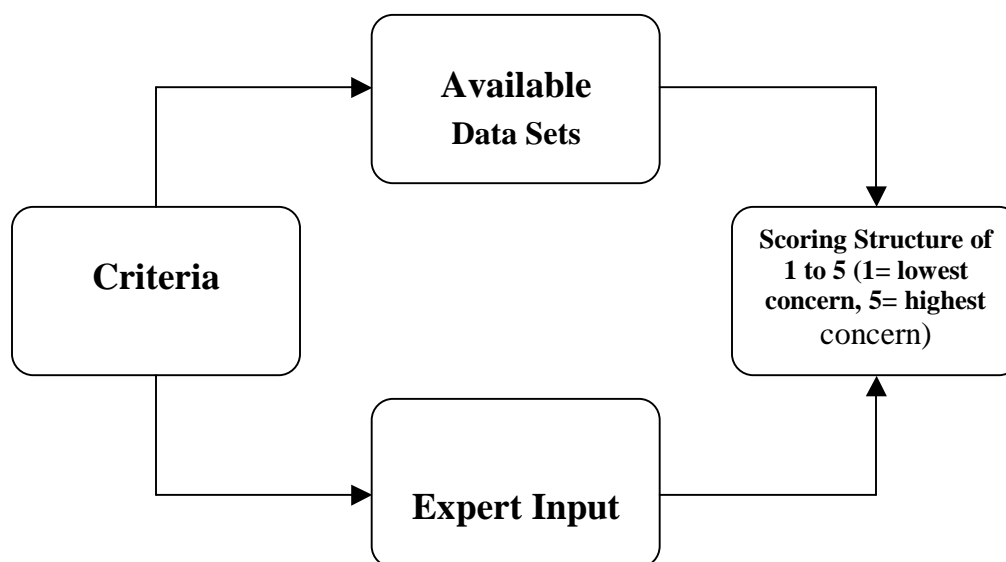


Figure 2. Region 6 GIS Screening Tool system process

a. Water Quality

The water quality criterion is separated into nineteen subgroups of criteria including surface water use, water quality (STORET data), rainfall, water releases, surface water quantity, distance to surface water, ground water probability, ground water quality, unified watershed assessment (state priority data), Clean Water Act 303(d) segments (state priority data), average stream flow, sole source aquifer, 500 year floodplain, aquifer/geology rating, channelization, individual well water, septic tank and cesspool use, Toxic Release Inventory (TRI) reported water releases, and soil permeability (Table 15). The water quality criterion addresses both the Chemical and Physical Characteristics and the Hydrology and Geomorphology SAB categories of analysis (See Table 29 and Table 30).

Table 15. Region 6 GISST Water Quality Criterion data layers

Data layer	Data Analysis/Rationale
Surface Water Use	The surface water use criterion is a degree of vulnerability input in the GISST algorithm and may be addressed with surface water quality data available from the following databases: Clean Water Act, Section 305 (b); Oklahoma State Water Quality Inventory Reports, 1994, US EPA; National Hydrography Database; and National Water Quality Standards Database. The data may be used to calculate the percentages of surface waters supporting designated use for the geographic area and scale of any given project. GISST scores (1 to 5) may be applied according to percentages of surface waters supporting designated use.
Water Quality (STORET Data)	The water quality (Storet Data) criterion is used as a degree of vulnerability input and may be addressed with water quality data available from the following databases: STORET Database, 1996, Office of Water, US EPA and Surf Your Watershed, US EPA Website. The STORET data displays exceedances of chemical concentration greater than the Safe Drinking Water Act Maximum Concentration Levels. This data may be used to calculate the number of water quality exceedances/area (ft ²). GISST scores (1 to 5) may be applied according to the number of water quality exceedances/area (ft ²).
Rainfall	The rainfall criterion is used as a DV input and may be addressed with rainfall data available from the following database: HUMUS - Hydrologic Unit Modeling for the United States, 1995, USDA/NRCS, USDA/ARS, and Texas A&M University. The HUMUS database provides rainfall data in inches/year. GISST scores (1 to 5) may be applied to this data according to rainfall inches/year.
Water Releases	The water releases criterion is used as a degree of vulnerability input and a degree of impact input and may be addressed with data available from the following databases: Toxic Release Inventory, 2000, US EPA and Hydrologic Unit Maps of the Conterminous U.S., 1994, US Geological Survey. GISST scores (1 to 5) may be applied to this data according to lbs released to an area. The area of analysis may be broken into 1 km grid cells for GISST criteria computation.
Surface Water Quantity	The surface water quantity criterion is used as a degree of vulnerability input and may be addressed with data available from the following databases: TIGER/Line Files, Census 2000; State Soil Geographic Database (STATSGO), NRCS; and National Hydrography Dataset, 1999, USGS. GISST scores (1 to 5) may be applied to this data according to mi ² /mi ² shore or stream length.

Table 15 continued. Water Quality Criterion data layers

Distance to Surface Water	The distance to surface water criterion is used as a degree of vulnerability input and may be addressed with data available from the following databases: TIGER/Line Files, RF3 Data, 2001, and National Hydrography Dataset, 1999, USGS. Vulnerable surface waters are those in the TIGER 2001 database and distance to surface water is measured as straight line distance from the outer boundary of a federal facility pollution source with no buffer zone. GISST scores (1 to 5) may be applied to this data according to distance (ft).
Ground Water Probability	The ground water probability criterion is used as a degree of vulnerability input and may be addressed with data available from the following databases: Statistical Summary of Groundwater Quality Data: 1986-1991 for the Major Groundwater Basins in Oklahoma, 1993, Oklahoma Water Resources Board; Downloadable ten acre grid soils data files from NRCS, 1996; and Oklahoma STATSGO Database, 1996, NRCS. GISST scores (1 to 5) may be applied to this data according to the probability of ground water in a 10-acre area around federal facility pollution sources being within 6-8 ft. of surface.
Ground Water Quality	The ground water quality criterion is used as a degree of vulnerability input and may be addressed with data available from the following databases: Statistical Summary of Groundwater Quality Data: 1986-1991 for the Major Groundwater Basins in Oklahoma, 1993, Oklahoma Water Resources Board and Oklahoma STATSGO Database, 1996, NRCS. GISST scores (1 to 5) may be applied to this data according to the mean nitrate-nitrite concentration (mg/L) of ground water. The area of analysis may be broken into 1 km grid cells for GISST criteria computation.
Unified Watershed Assessment (State Priority Data)	The Unified Watershed Assessment (State Priority Data) criterion is used as a degree of vulnerability input and may be addressed with data available from the following databases: Clean Water Act, Section 305 (b), State Water Quality Inventory Reports, 303 (d) List, 1994, US EPA; National Hydrography Database; and National Water Quality Standards Database. GISST scores (1 to 5) may be applied to this data according to whether the watershed is supporting designated use.
Clean Water Act 303(d) Segments (State Priority Data)	The Clean Water Act 303(d) Segments (State Priority Data) criterion is used as a degree of vulnerability input and may be addressed with data available from the following databases: Stream Segments 2000, TCEQ and Texas Interstate 69 Baseline Analysis Grid, 2003, EPA. Segments listed as impaired are used in this criterion and receive a score of 5. GISST scores (1 to 5) may be applied to this data according to whether an impaired segment is present in the grid cell. The area of analysis may be broken into 1 km grid cells for GISST criteria computation.

Table 15 continued. Water Quality Criterion data layers

Average Stream Flow	The average stream flow criterion is used as a degree of vulnerability input according to the assumption that the less average stream flow of the geographic area, the greater the concern for contaminant loading in a water body. The criterion may be addressed with data available from the following databases: STORET Database, 1996, Office of Water, US EPA and Surf Your Watershed, US EPA Website. GISST scores (1 to 5) may be applied to this data according to the mean surface water flow (ft ³ /sec) of the watershed or project area. The area of analysis may be broken into 1 km grid cells for GISST criteria computation.
Sole Source Aquifer (SSA)	The sole source aquifer (SSA) criterion is used as a degree of vulnerability input in the GISST system. A Sole Source Aquifer is an aquifer designated by EPA as the “sole or principal source” of drinking water for a given service area (supplies 50% or more). The criterion may be addressed with data available from the following databases: U.S. EPA 1996 Sole source aquifer GIS layer. GISST scores (1 to 5) may be applied to this data according to whether an SSA is beneath the site.
500 yr Floodplain	The 500 yr floodplain criterion is used as a degree of vulnerability input and a degree of impact input and may be addressed with data available from the following databases: Q3 Flood Data (mid-90's data), Federal Emergency Management Agency. GISST scores (1 to 5) may be applied to this data according to the percent of the geographic area that is within the 500 yr floodplain.
Aquifer/Geology Rating	The aquifer/geology rating criterion is used as a degree of vulnerability input and may be addressed with data available from the following databases: Geology of the coterminous United States at 1:2,500,000 scale- a digital representation of King, P. B., and H. M. Beikman map 1974, US Geological Survey Digital Data Series DDS-11; Hydrologic unit maps of the coterminous United States, 1994, US Geological Survey; and DRASTIC Typical Ratings, 1987, US EPA. GISST scores (1 to 5) may be applied to this data according to aquifer media.
Channelization	The channelization criterion is used as a degree of vulnerability input and may be addressed with data available from the following databases: TIGER/Line Files, Census 2000, US Census Bureau. Channelization refers to canals, ditches, and aqueducts and is not specific to channelization of a specific use or size. GISST scores (1 to 5) may be applied to this data according to the density of channels in the watershed (mi/mi ²). The area of analysis may be broken into 1 km grid cells for GISST criteria computation.
Individual Well Water	The individual well water criterion is used as a degree of vulnerability input and may be addressed with data available from the following databases: Census 2000 Summary File 3 – (AR, LA, NM, OK, TX), US Census Bureau. GISST scores (1 to 5) may be applied to this data according to the percent of the population with individual water source. The area of analysis may be broken into 1 km grid cells for GISST criteria computation

Table 15 continued. Water Quality Criterion data layers

Septic Tank and Cesspool Use	The septic tank and cesspool use criterion is used as a degree of vulnerability input and may be addressed with data available from the following databases: Census 2000 Summary File 3 – (AR, LA, NM, OK, TX), US Census Bureau. GISST scores (1 to 5) may be applied to this data according to the percent of the population with septic tank/cesspool. The area of analysis may be broken into 1 km grid cells for GISST criteria computation.
TRI Reported Water Releases	The TRI Reported Water Releases criterion is used as a degree of impact input and may be addressed with data available from the following databases: Toxic Release Inventory, 2000, US EPA. GISST scores (1 to 5) may be applied to this data according to lbs of toxic chemicals released to water.
Soil Permeability	The soil permeability criterion is used as a degree of vulnerability input and may be addressed with data available from the following databases: Downloadable ten acre grid soils data files from NRCS, 1996 and Oklahoma STATSGO Database, 1996, NRCS. GISST scores (1 to 5) may be applied to this data according to the rating (in/hr) of soil permeability within a 10-acre buffer around federal facility pollution source.

b. Ecological

Within the ecological criterion, Region 6 created fifteen subgroups of criteria including agricultural lands, wetlands, wildlife habitat, wildlife habitat quality, landscape texture, landscape aggregation, patch area, habitat fragmentation, federally listed endangered and threatened species, state listed endangered and threatened species, endangered species act compliance, ecologically significant stream segments, road density, watershed/geographic area, and density of managed lands (Table 16). The ecological criterion addresses both the Landscape Condition and the Biotic Condition SAB categories of analysis (See Table 27 and Table 28).

Table 16. Ecological Criterion data layers

Data layer	Data Analysis/Rationale
Agricultural Lands	<p>The agricultural lands criterion is used as a degree of vulnerability input and a degree of impact input and may be addressed with data available from the following databases: 2000 National Land Cover Database compiled from Landsat satellite TM imagery (circa 1992) with a spatial resolution of 30 meters, U.S. Geological Survey. Agricultural lands are represented by the lands classified as orchards/vineyards/other, pasture/hay, row crops, small grains, and fallow. GISST scores (1 to 5) may be applied to this data according to the percent of area that is classified as agricultural land, where areas with a higher percentage of agricultural land are given a higher score. The area of analysis may be broken into 1 km grid cells for GISST criteria computation.</p>
Wetlands	<p>The wetlands criterion is used as a degree of vulnerability input and a degree of impact input and may be addressed with data available from the following databases: 2000 National Land Cover Database compiled from Landsat satellite TM imagery (circa 1992) with a spatial resolution of 30 meters, U.S. Geological Survey. Wetlands are represented by the lands classified as woody wetlands and emergent herbaceous wetlands. GISST scores (1 to 5) may be applied to this data according to the percent of area that is classified as wetlands. The area of analysis may be broken into 1 km grid cells for GISST criteria computation.</p>
Wildlife Habitat	<p>The wildlife habitat criterion is used as a degree of vulnerability input and a degree of impact input and may be addressed with data available from the following databases: 2000 National Land Cover Database compiled from Landsat satellite TM imagery (circa 1992) with a spatial resolution of 30 meters, U.S. Geological Survey. Habitats are represented by forest lands, shrublands, grasslands, wetlands, and open water. GISST scores (1 to 5) may be applied to this data according to the percent of area that is classified as wildlife habitat. The area of analysis may be broken into 1 km grid cells for GISST criteria computation.</p>
Wildlife Habitat Quality (Land Use Data)	<p>The wildlife habitat quality (land use data) criterion is used as a degree of vulnerability input and may be addressed with data available from the following databases: 2000 National Land Cover Database compiled from Landsat satellite TM imagery (circa 1992) with a spatial resolution of 30 meters, U.S. Geological Survey. Land uses are given a rank according to wildlife habitat quality value and 5 is the highest value. The rankings are: 1 = industrialized/transportation/commercial areas; 2 = high intensity residential; 3 = low intensity residential, urban recreational grasses, bare rocks, sand, and clay, transitional areas; 4 = agricultural; 5 = wildlife habitat defined as rangeland, wetlands, forest lands, woodlands, herbaceous uplands, shrublands, open water. The percent of each land use in the watershed is multiplied by the rank of the land use. All values are then summed. GISST scores (1 to 5) may be applied to this data according to the cumulative land use ranking.</p>

Table 16 continued. Ecological Criterion data layers

Landscape Texture	The landscape texture criterion is used as a degree of vulnerability input and may be addressed with data available from the following databases: 2000 National Land Cover Database compiled from Landsat satellite TM imagery (circa 1992) with a spatial resolution of 30 meters, U.S. Geological Survey. Landscape texture is measured by the metric Angular second moment (ASM), calculated using the APACK software and serves as a measure of core habitat. GISST scores (1 to 5) may be applied to this data according to the ASM.
Landscape Aggregation	The landscape aggregation criterion is used as a degree of vulnerability input and may be addressed with data available from the following databases: 2000 National Land Cover Database compiled from Landsat satellite TM imagery (circa 1992) with a spatial resolution of 30 meters, U.S. Geological Survey. Landscape aggregation is measured by the metric Aggregation Index (AI) calculated using the APACK software where aggregation is degree to which certain land cover types are aggregated within landscapes. GISST scores (1 to 5) may be applied to this data according to the AI.
Patch Area (normalized, average)	The patch area (normalized, average) criterion is used as a degree of vulnerability input and may be addressed with data available from the following databases: 2000 National Land Cover Database compiled from Landsat satellite TM imagery (circa 1992) with a spatial resolution of 30 meters, U.S. Geological Survey. Patch area is measured by the metric normalized average patch area (AAM) calculated using the APACK software. GISST scores (1 to 5) may be applied to this data according to the ratio of the average of each patch area relative to the area of a square with the same perimeter.
Habitat Fragmentation	The habitat fragmentation criterion is used as a degree of vulnerability input and may be addressed with data available from the following databases: 2000 National Land Cover Database compiled from Landsat satellite TM imagery (circa 1992) with a spatial resolution of 30 meters, U.S. Geological Survey. Fragmentation was addressed by calculating the area to perimeter ratio of patches. GISST scores (1 to 5) may be applied to this data according to the perimeter to area ratio.
Federally Listed Endangered and Threatened Species	The federally listed endangered and threatened species criterion is used as a degree of impact input and may be addressed with data available from the following databases: Biological Conservation Database (points), 2002, TPWD and Texas Interstate 69 Baseline Analysis Grid, 2003, EPA. GISST scores (1 to 5) may be applied to this data according to whether elemental occurrences are present in the area. The area of analysis may be broken into 1 km grid cells for GISST criteria computation.
State Listed Endangered and Threatened Species	The state listed endangered and threatened species criterion is used as a degree of impact input and may be addressed with data available from the following databases: Biological Conservation Database (points), 2002, TPWD and Texas Interstate 69 Baseline Analysis Grid, 2003, EPA. GISST scores (1 to 5) may be applied to this data according to whether elemental occurrences are present in the area. The area of analysis may be broken into 1 km grid cells for GISST criteria computation.

Table 16 continued. Ecological Criterion data layers

Endangered Species Act Compliance	The Endangered Species Act compliance criterion is used as a degree of impact input and may be addressed with data available from the following databases: Information supplied by facility. GISST scores (1 to 5) may be applied to this data according to Section 7 compliance in the area.
Ecologically Significant Stream Segments	The ecologically significant stream segments criterion is used as a degree of vulnerability input and may be addressed with data available from the following databases: Ecologically Significant Stream Segments, 2000-2001, TPWD and Texas Interstate 69 Baseline Analysis Grid, 2003, EPA. GISST scores (1 to 5) may be applied to this data according to ecologically significant stream segments presence in the area.
Road Density	The road density criterion is used as a degree of vulnerability input and may be addressed with data available from the following databases: TIGER/Line Files, Census 2000, U.S. Census Bureau and National Hydrography Dataset, 2000, U.S. Geological Survey. GISST scores (1 to 5) may be applied to this data according to road density (mi/mi ²).
Watershed/Geographic Area	The watershed/geographic area criterion is used as a degree of vulnerability input and may be addressed with data available from the following databases: Facility boundary data submitted by facility (received upon request or taken from EPA RCRA, NPDES, NEPA, or other regulatory files) and Hydrologic Unit Maps of the Conterminous U.S., 1994, U.S. Geological Survey. Facilities include defense facilities, agriculture operations, municipal works, private industry, state and local government operations. GISST scores (1 to 5) may be applied to this data according to percent of watershed or geographic area that is occupied by facilities.
Density of Managed Lands	The density of managed lands criterion is used as a degree of impact input and may be addressed with data available from the following databases: Consolidated Managed Land for Texas, 2003, EPA. GISST scores (1 to 5) may be applied to this data according to the presence of managed lands in the area.

c. Air Quality

Within the air quality criterion, Region 6 developed three subgroups of criteria including air quality, ozone non-attainment, and TRI reported air releases (Table 17). The air quality criterion addresses the Chemical and Physical Characteristics SAB categories of analysis (Table 29).

Table 17. Air Quality Criterion data layers

Data layer	Data Analysis/Rationale
Air Quality	The air quality criterion is used as a degree of vulnerability input and may be addressed with data available from the following databases: Ozone nonattainment GIS layer created from Ozone Nonattainment Greenbook, 2003, US EPA. GISST scores (1 to 5) may be applied to this data according to the distance from nonattainment area for any of the criteria air pollutants: ozone, lead, particulates, CO, SOx, and Nox.
Ozone Nonattainment	The ozone nonattainment criterion is used as a degree of vulnerability input and may be addressed with data available from the following databases: TIGER Counties Census, 2001, coverage by EPA and Nonattainment Areas, 1998, TCEQ. GISST scores (1 to 5) may be applied to this data according to the project location (outside, near, or inside nonattainment area).
TRI Reported Air Releases	The TRI reported air releases criterion is used as a degree of impact input and may be addressed with data available from the following databases: Toxic Release Inventory, 2000, US EPA. GISST scores (1 to 5) may be applied to this data according to lbs of air releases from stack and fugitive emissions.

d. Socioeconomic

The socioeconomic criterion addresses environmental justice and other social and economic issues relevant for assessing potential environmental impacts. The socioeconomic criterion has eighteen subgroups of criteria:

- i. Colonias (unincorporated residential areas where municipal services are lacking)
- ii. High School Education
- iii. Educational Achievement Ranking
- iv. Economic (environmental justice)
- v. Minority (environmental justice)
- vi. Age (7 > Age = 55 years old)
- vii. Children (population < 7 years old)
- viii. Older Population (> 55 years old)
- ix. Pregnancy (population < 1 years old)
- x. Population Change
- xi. Population Density (persons per sq.mi.)
- xii. Total Population
- xiii. Houses Lacking Complete Plumbing

- xiv. Telephone Communications
- xv. Ability to Speak English
- xvi. Linguistic Isolation
- xvii. Foreign Born
- xviii. Cultural Resources

e. Toxicity

The toxicity criterion has four subgroups of criteria including toxicity weighted TRI water releases; toxicity weighted TRI air releases; toxicity weighted RCRA-BRS₂ data; and other industries, pollution sources, or protected lands (Table 18).

Table 18. Toxicity Criterion data layers

Data layer	Data Analysis/Rationale
Toxicity Weighted TRI Water Releases	The toxicity weighted TRI water releases criterion is used as a degree of impact input and may be addressed with data available from the following databases: Toxic Release Inventory TRI Data: SARA Community Right-to-know, 2000 [updated annually], U.S. EPA and Emergency Planning and Community Right-to-Know Act (EPCRA), Section 313, Toxic Release Inventory (TRI) 2000 chemical release data, 2002, U.S. EPA. GISST scores (1 to 5) may be applied to this data according Health Risk Index score for TRI water releases.
Toxicity Weighted TRI Air Releases	The toxicity weighted TRI air releases criterion is used as a degree of impact input and may be addressed with data available from the following databases: Toxic Release Inventory TRI Data: SARA Community Right-to-know, 2000 [updated annually], U.S. EPA. GISST scores (1 to 5) may be applied to this data according Health Risk Index score for TRI air releases. This data layer addresses the University of Florida stressors category of analysis, toxic materials, and the subcategory, air pollution.
Toxicity Weighted RCRA-BRS ₂ Data	The toxicity weighted RCRA-BRS ₂ data criterion is used as a degree of impact input and may be addressed with data available from the following databases: Biennial Report System (BRS), 2000, U.S. EPA. GISST scores (1 to 5) may be applied to this data according to RCRA facility waste (tons). This data layer addresses the University of Florida stressors category of analysis, toxic materials, and the subcategories, water quality impacts and soil contamination.
Other Industries, Pollution Sources, or Protected Lands	The other industries, pollution sources, or protected lands criterion is used as a degree of vulnerability and degree of impact input and may be addressed with data available from the following databases: Envirofacts Database, 2002, U.S. EPA; Toxic Release Inventory, 2002, U.S. EPA; National Priority List sites, 2002, U.S. EPA; Permitted Industrial & Hazardous Waste Sites, 1996, TCEQ; Municipal Solid Waste Landfills, 1996, TCEQ; Radioactive Waste Sites, 2000, TCEQ; and Superfund Sites, 2002, TCEQ. GISST scores (1 to 5) may be applied to this data according to number of sites within a 2 mi buffer.

f. CAFO (Concentrated Animal Feeding Operations)

The CAFO (concentrated animal feeding operations) criterion has thirteen subgroups of criteria:

- i. Livestock Population Density (Animal Units/CAFO Total Acres)
- ii. Lagoon Loading Rate
- iii. Lagoon Treatment System Liner
- iv. Land Application Technology
- v. Nitrogen Budget
- vi. Phosphorus Budget
- vii. Lagoon Storage Capacity
- viii. Well Head Protection
- ix. Employment in Cafo Industry
- x. Odor (from CAFOs)
- xi. Transportation Near Cafos
- xii. Density of Cafos
- xiii. Proximity of Cafos

2. Summary of the Region 6 GIS Screening Tool (GISST)

EPA Region 6 GIS Screening Tool (GISST) is primarily an environmental impact assessment tool that incorporates a vast array of GIS data and applies a consistent scoring structure to support sound environmental decision making. The system is designed to be flexible so that it can be applied to a variety of programs or projects and the system may be applied at spatial scales ranging from local to regional. The GISST system consists of criteria (environmental vulnerability and environmental impact criteria) and imposes a scoring structure using available data sets and expert input. Criteria are evaluated using a mathematical formula and the scoring structure consists of the criteria and a ranking system, which uses 1 to indicate low environmental concern and 5 to indicate high concern. Assessment criteria incorporated in the GISST system include the broad groups of water quality, ecological, air quality, socioeconomic, toxicity, and CAFO (concentrated animal feeding operations). Advantages of GISST include the flexibility of the system to add new criteria at any time and the ability to apply GISST at varying scales for local to regional projects.

As an impact assessment tool, GISST is more similar to the Region 2 NEPAAssist tool than to the critical ecosystem assessment projects conducted in Region 4 and Region 5. However, though Region 6 GISST is an impact assessment application, it incorporates a wide variety of data and analyses relevant to regional-scale critical ecosystem assessments. Many of the GIS data incorporated into the application are useful for identifying both ecologically significant areas and relevant stressors including:

- 1) Surface water and ground water quality
- 2) Aquifer significance
- 3) Channelization
- 4) Floodplains
- 5) Air quality

- 6) Pollution sources
- 7) Landscape composition
- 8) Wetlands
- 9) Listed species
- 10) Wildlife habitat
- 11) Habitat fragmentation
- 12) Road densities
- 13) Managed lands

The index ranking approach is also similar to the ranked index approaches used in the prioritization phase of the Region 4 SEF project and Region 5 CrEAM. As discussed in the summaries for the Region 4 and Region 5 projects, such data address many aspects of critical ecosystem identification but not all. More specific data are needed to more thoroughly identify areas needed to conserve biodiversity, especially viable populations of focal species, and more information and tools are needed to address ecological services including hydrological and air resource protection.

E. Region 7 Synoptic Assessment of Wetland Function Process

Schweiger, E.W., S.G. Leibowitz, J.B. Hyman, W.E. Foster, and M.C. Downing. 2002. Synoptic assessment of wetland function: a planning tool for protection of wetland species biodiversity. *Biodiversity and Conservation* 11: 379–406.

Diamond, D.D. and T. Gordon. 2003. *Final Report, State-based Ranking of Watersheds Using the Synoptic Assessment of Wetland Function Model*. Submitted to the U.S. Environmental Protection Agency, Region 7, Kansas City, Kansas.

EPA Region 7 has developed a GIS assessment tool for wetland function that is intended to maximize benefits to wetland biodiversity in the Midwest states, Missouri, Iowa, Nebraska, and Kansas. The method allows the prioritization of sub-basins (delineated by US Geological Survey eight-digit Hydrologic Unit Codes) within the region in which conservation action would be expected to have the most benefits for wetland biodiversity. The study area included 225 sub-basins within Region 7. The assessment acts as a screening tool to target resource management and conservation efforts at a sub-basin scale; however, there may be individual wetlands within lower ranked sub-basins that would provide greater biodiversity benefit than individual wetlands in higher ranked sub-basins. Therefore, the assessment is intended to identify sub-basins where more costly site-specific information should be obtained. It is also important to understand that the calculated risks are relative to the overall study area. Thus, a sub-basin may receive a high score in an analysis at the state level and be much lower ranked in a region-wide analysis.

1. Model Description

Region 7 developed three indices to prioritize sub-basins within the region (see Figure 3). In developing the ranking of watersheds for the region, five indicators of habitat quality, two indicators of the species sensitivity using 612 wetland species (defined as species that require or use wetlands), and species endemism scores were combined in different ways to derive the three indices (see Figure 3). Region 7 developed all habitat indicators using the National Land Cover Dataset (NLCD). Region 7 used a 1995 Natural Heritage Program database to create the species sensitivity and endemism indicators. The model calculated index values for each sub-basin, which were then ranked in terms of wetland importance. A rank of 1 indicates that the sub-basin should receive the highest priority in a section 404 permit review in order to avoid increases in wetland species extirpation risk. The sub-basin scores for each index ranged from 1 to 216. The distributions of scores for each index were then classified using the Fisher-Jenks procedure for determining natural breaks in data distribution. In the study, Region 7 did not combine the three primary indices, but instead compared them in terms of index score correlation and general spatial patterning. The scores of all three of the indices were highly correlated and general spatial patterning of the ranks was qualitatively similar.

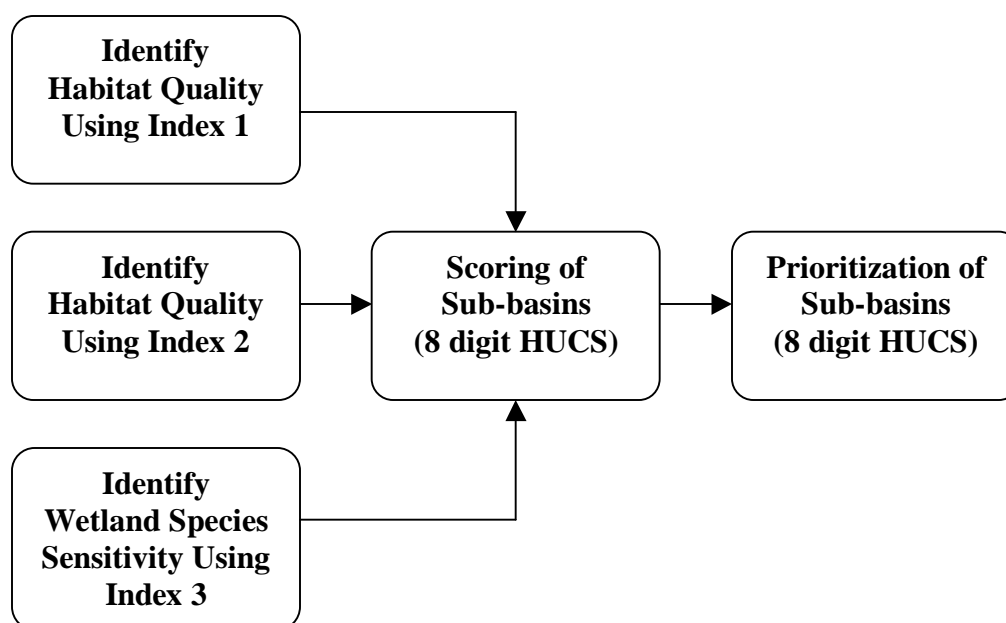


Figure 3. Synoptic Assessment of Wetland Function Modeling process

a. Index 1

Index 1 combined two wetland habitat quality indicators: agricultural density and wetland density (Table 19). The model used the species sensitivity indicator, global rarity score, and an endemism score to calculate Index 1 (Table 19). National Land Cover Dataset (NLCD) was the input data for all habitat indices. Region 7 evaluated the species sensitivity and endemism indicators using the 1995 Natural Heritage Program database. To calculate the final score of each basin for Index 1, the model first standardized values for agricultural density and wetland density and then averaged and multiplied by the sensitivity and endemism score for each species across the basin. Finally, the values calculated for all species across the basin were summed. Index 1 addresses both the Landscape Condition and the Biotic Condition SAB categories of analysis (Table 27 and 28).

Table 19. Region 7 Index 1 data layers

Data layer	Data Analysis/Rationale
Agricultural Density	The first data layer, indicating agricultural density, represented the percent of all agricultural land within the sub-basins. Low agricultural density was considered to be a positive indicator for wetland habitat quality. Classes of the National Land Cover Dataset that were considered agriculture included row crops, small grains, and fallow land cover.
Wetland Density	The second data layer, indicating wetland density, represented the percent of all wetlands within each sub-basin. High wetland density was considered to be a positive indicator for wetland habitat quality. Wetland classes of the National Land Cover Dataset included open water, woody wetlands, and emergent herbaceous wetlands. Wetland density was calculated using Fragstats 3.3.
Global Rarity Score	A total of 612 wetland species were identified in the Region 7 Heritage database. The 1995 Natural Heritage Program database includes a global rarity field (G-rank), which ranks species from common (G5) to rare (G1). The global rarity score for Index 1 was calculated by assigning scores to each G-rank for each species. Scores were applied according to the median number of viable occurrences: G1 = 1000, G2 = 250, G3 = 50, G4 = 25, and G5 = 10.
Endemism	The 1995 Natural Heritage Program data was also used to calculate an endemism score for each sub-basin. If a species occurs in multiple sub-basins, its risk of regional extirpation was considered to be low if the species were to experience a local loss. Endemism scores were calculated for each species across the sub-basins as $1/N_i$, where N is the number of sub-basins that the species occurs within in the region.

b. Index 2

Index 2 combined five wetland habitat quality indicators: agricultural density, wetland density, wetland habitat diversity, mean distance between wetland patches, and mean wetland patch size (Table 20). Index 2 also included the species sensitivity indicator, global rarity score, and an endemism score (Table 20). National Land Cover Dataset (NLCD) was the input for all habitat indices. Region 7 evaluated the species sensitivity and endemism indicators using the 1995 Natural Heritage Program database. To calculate the final score of each basin for Index 2, the model first standardized the values for all five habitat quality indicators and then averaged and multiplied by the sensitivity and endemism score for each species across the basin. Finally, the values calculated for all species across the basin were summed. Index 2 addresses both the Landscape Condition and the Biotic Condition SAB categories of analysis (Table 27 and Table 28).

Table 20. Index 2 data layers

Data layer	Data Analysis/Rationale
Agricultural Density	The first data layer, indicating agricultural density, represented the percent of all agricultural land within the sub-basins. Low agricultural density was considered to be a positive indicator for wetland habitat quality. Classes of the National Land Cover Dataset that were considered agriculture included row crops, small grains, and fallow land cover.
Wetland Density	The second data layer, indicating wetland density, represented the percent of all wetlands within each sub-basin. High wetland density was considered to be a positive indicator for wetland habitat quality. Wetland classes of the National Land Cover Dataset included open water, woody wetlands, and emergent herbaceous wetlands. Wetland density was calculated using Fragstats 3.3.
Wetland Habitat Diversity	Wetland diversity, the third indicator, was calculated by using the Shannon-Weiner diversity index to represent the proportion of the landscape occupied by each wetland type. Fragstats 3.3 was used to generate the data layer. High wetland habitat diversity was considered to be a positive indicator for wetland habitat quality. Wetland classes of the National Land Cover Dataset included open water, woody wetlands, and emergent herbaceous wetlands.
Mean Distance Between Wetland Patches	The fourth indicator, mean distance between wetland patches, was calculated using the mean nearest neighbor function in Fragstats 3.3. The average of all patch distances was derived and the mean nearest neighbor calculation was weighted by the inverse of the number of wetland patches in the sub-basin. Low mean distance between wetland patches was considered to be a positive indicator for wetland habitat quality. Wetland classes of the National Land Cover Dataset that were combined in this calculation included open water, woody wetlands, and emergent herbaceous wetlands.
Mean Wetland Patch Size	The fifth indicator, mean wetland patch size, was calculated using Fragstats 3.3. A greater mean wetland patch size was considered to be a positive indicator for wetland habitat quality. Wetland classes of the National Land Cover Dataset included open water, woody wetlands, and emergent herbaceous wetlands.
Global Rarity Score	A total of 612 wetland species were identified in the Region 7 Heritage database. The 1995 Natural Heritage Program database includes a global rarity field (G-rank), which ranks species from common (G5) to rare (G1). The global rarity score for Index 2 was calculated by assigning scores to each G-rank for each species. Scores were applied according to the median number of viable occurrences: G1 = 1000, G2 = 250, G3 = 50, G4 = 25, and G5 = 10.
Endemism	The 1995 Natural Heritage Program data was also used to calculate an endemism score for each sub-basin. If a species occurs in multiple sub-basins, its risk of regional extirpation was considered to be low if the species were to experience a local loss. Endemism scores were calculated for each species across the sub-basins as $1/N_i$, where N is the number of sub-basins that the species occurs within in the region.

c. Index 3

Index 3 combined two indicators related to wetland species sensitivity: the heritage species global rarity score and a modifier to the global rarity score based on the habitat quality indicators of Index 2 (Table 21). An endemism score for each species was also included in the calculation of Index 3 (Table 21). Region 7 evaluated the species sensitivity and endemism indicators using the 1995 Natural Heritage Program database. To calculate the final score of each basin for Index 3, the model first modified the global rarity score for each species by the habitat quality value, and then multiplied by an endemism score. Finally, the values calculated for all species across the basin were summed. Index 3 addresses both the Landscape Condition and the Biotic Condition SAB categories of analysis (See Table 27 and 28).

Table 21. Index 3 data layers

Data layer	Data Analysis/Rationale
Global Rarity Score	A total of 612 wetland species were identified in the Region 7 Heritage database. The 1995 Natural Heritage Program database includes a global rarity field (G-rank), which ranks species from common (G5) to rare (G1). The global rarity score for Index 3 was calculated by assigning scores to each G-rank for each species. Scores were applied according to the median number of viable occurrences: G1 = 1000, G2 = 250, G3 = 50, G4 = 25, and G5 = 10.
Habitat Quality Categorical Modifier to the Global Rarity Score	Principal components analysis (PCA) was used to evaluate the five habitat indicators: agricultural density, wetland density, wetland diversity, mean distance between wetland patches, and mean wetland patch size, for each sub-basin to modify the global rarity score. The location of each sub-basin in the multivariate space defined by the PCA was used to categorize each sub-basin into low, high, or neutral habitat quality and to examine its departure from the mean. If PCA values for a sub-basin were less than 1 standard deviation from the mean, they were considered neutral and assigned a value of zero. Sub-basins greater than 1 but less than 2 standard deviations from the mean were assigned a modifier value of 1 or -1 depending upon which quadrant it fell into. Sub-basins greater than 2 standard deviations from the mean had a modifier value of 2 or -2. Sub-basins falling into quadrants that were characterized by low quality habitat were assigned negative values, and sub-basins falling into quadrants characterized by high quality habitat were assigned positive values. The modifier values were used to adjust the G-rank scores such that, if a species fell within a sub-basin with a modifier of zero, the G-rank score remained the same. The range of G-ranks was expanded to compensate for modified G-ranks and included a range of -G1 to G7 with the following scores: -G1 = 7500, G0 = 3000, G1 = 1000, G2 = 250, G3 = 50, G4 = 25, G5 = 10, G6 = 5, and G7 = 1. Each sub-basin possessed a modifier to the G-rank for global rarity based on the habitat quality indicators.
Endemism	The 1995 Natural Heritage Program data was also used to calculate an endemism score for each sub-basin. If a species occurs in multiple sub-basins, its risk of regional extirpation was considered to be low if the species were to experience a local loss. Endemism scores were calculated for each species across the sub-basins as $1/N_i$, where N is the number of sub-basins that the species occurs within in the region.

2. Summary of the Region 7 Synoptic Assessment of Wetland Function Process

The Region 7 synoptic assessment of wetland function was developed to identify priority wetlands for conserving wetland species biodiversity. The method prioritizes sub-basins (eight-digit Hydrologic Unit Codes) within the region in which conservation actions would be expected to have the most benefits for wetland biodiversity conservation. Region 7 developed three separate indices to prioritize sub-basins within the region, which all incorporated various indicators of habitat quality and focal species priority. Region 7 developed all habitat indicators using the National Land Cover Dataset (NLCD), and used the 1995 Natural Heritage Program database to develop the focal species priority indicators. Index values were derived for each sub-basin, which were then ranked in terms of wetland importance. Region 7 did not combine the results of the three indices, but instead compared them in terms of index score correlation and general spatial patterning. The first habitat quality index combined the following indicators:

- 1) Agricultural density
- 2) Wetland density
- 3) Global rarity score
- 4) Endemism score

The second habitat quality index included the same four indicators but also added wetland habitat diversity, mean distance between wetland patch centers, and mean wetland patch size. The third index combined the global rarity score and endemism score indices with a habitat quality categorical modifier to the global rarity score. In this application of the model, the scores of all three of the indices were highly correlated and general spatial patterning of the ranks was qualitatively similar.

The assessment serves as a screening tool to target resource management and conservation efforts at a sub-basin scale, which is an important distinction between this application and especially the Region 4 and Region 5 critical ecosystem assessment projects. The Region 7 represents a “geographic summary” assessment approach, where large geographical units are identified as priorities based on the comparison of relevant ecological data summarized for each geographic unit. In contrast, the Region 4 and Region 5 projects can be described as primarily (though not exclusively) pixel-based, or cell-based, decision support models, where the decision units are at least relatively small geographic areas that more specifically identify areas containing ecological resources of interest or stressors of concern. Though more spatially specific approaches may be preferred when feasible, both approaches provide benefits for regional-scale assessments of critical ecosystems and are potentially complementary. The primary reason for the utility of both approaches is that many available GIS data and analytical methods lend themselves to the development of summary statistics for larger geographic units versus more specific identification of areas of significance. For example, indices such as mean patch sizes and mean distance between patches are at least more easily applied to summary geographic units than to pixel-based approaches. As noted by the authors of the Region 7 synoptic wetland assessment, these approaches can be complementary. Larger geographic units can be used where appropriate to summarize data and utilize methods difficult to apply to more spatially-explicit approaches in order to prioritize them. More spatially explicit approaches can then be used to identify the specific areas

of ecological significance within higher priority geographic units and to also identify specific areas within lower priority geographic units that are also worthy of conservation attention. Finally, it should be noted that the Region 7 methodology is currently being studied for application to a broader array of resources including priority uplands and the inclusion of additional indices to assess relative significance. This includes the development of representation or irreplaceability analyses that can be an important tool for assessing the importance of ecosystems, which is included in more detail in the discussion section of this report.

F. Region 8 Environmental Monitoring and Assessment Program (EMAP) Water Resources Assessment

The EPA Region 8 Environmental Monitoring and Assessment Program (EMAP) in conjunction with the EPA Office of Research and Development (ORD) and the U.S. Geological Survey (USGS) propose, with an expected completion date of 2005, to compile, analyze, and interpret available biological monitoring and stressor data to produce a Regional ecological assessment of stream condition within Region 8. Using a condition ranking of good, marginal and poor condition the assessment is designed to determine the length and location of streams with these conditions; inventory the condition of resources using the same ranking guide, and identify the frequency and magnitude of the stressors impacting resource condition along these streams. Additional goals are to determine the associations between conditions and stressors and predict locations of the condition classes and stressors within each assessment unit.

Preliminary work has progressed in a two-pronged approach by correspondence outreach to determine stakeholder needs, conduct interviews, and hold conversations with stakeholders to clarify the proposed EMAP approach. An EMAP pilot project has been conducted with the objectives to estimate current trends and status in selected indicators of ecological stream condition; to estimate geographic coverage and extent of project; to rank stressors affecting ecological stream condition; and to find associations between ecological stream condition and stresses.

The proposed assessment units or geographic area considered for investigation within Region 8 include:

- 1) Individual states (Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming) within Region 8
- 2) Individual or aggregated Omernik Level 3 ecoregions, watershed basins (Upper Missouri, Yellowstone, Upper Colorado)
- 3) Other unique areas such as physiographic provinces (Northern Plains and Southern Rockies of Colorado and Montana) or other watershed basins (Upper Missouri River, and Reservoirs)

The landscape reporting units for the assessment units in the EMAP-West are proposed to be 3km and 5km grid cell sizes.

1. Model Description

Analysis criteria include various characterizations of ecological conditions of streams and rivers. The indicators used in the pilot project include:

- 1) Fish, macroinvertebrate, and periphyton community structures
- 2) Physical habitat (in-stream and near-stream)
- 3) Ambient chemistry (nutrients and major ions)
- 4) Fish tissue (heavy metals and organic contaminants)
- 5) Watershed characteristics

Rankings for condition classes are qualitative: good, marginal, and poor. Landscape metrics will be used to characterize stressors and stream condition, and stressor association with surface water monitoring sites will be quantified by developing landscape indicators for each catchment/basin, landscape metrics for catchments/basins, and landscape models. Surface water measurements and indicators will be integrated with landscape metrics to produce landscape indicators represented by GIS data layers. These criteria are subdivided into categories representing biological and habitat integrity and various stressors. The data layers necessary to develop criteria/suitability ranking for each subgroup are discussed under each subgroup.

a. Biological and Habitat Integrity

Biological indicator species are unique environmental indicators that offer a signal of the biological condition within a watershed (Table 22). Biological indicators can warn of pollution or degradation in an ecosystem and can help sustain critical resources. Landscape models will be used to identify areas within each assessment unit having good, marginal, or poor ecological stream condition, and weighted indicators, derived from stream sampling, will be used for assessing the number and percentage of stream miles in each assessment unit that are in good, marginal, and poor condition. The biological and habitat integrity indicators address the Biotic Condition SAB categories of analysis (Table 28).

Table 22. Biological and Habitat Integrity indicators

Data layer	Data Analysis/Rationale
Fish assemblages Index of Biotic Integrity (IBI)	The type, number, health, and location of fish assemblages, based on the Index of Biological Integrity framework, indicate whether stream waters are clean or polluted, and if water quality is increasing or decreasing. This information, characterized by metrics and indices, will be incorporated into a stream dataset (presumably) indicating stream condition in miles and the percentage of naturally reproducing game fish populations and special status fish.
Macroinvertebrate assemblages (IBI)	Macroinvertebrates integrate environmental conditions and are sensitive to pollution, which is reflected by their location within a stream reach, favoring habitable areas with no or low levels of stressors. Contained within a stream dataset, information on macroinvertebrates will denote the percentage and length of stream condition, poor, marginal, or good.
Periphyton assemblages (community structure)	Periphyton are algae attached to stream substrate that integrates physical and chemical disturbances within the stream reach making them sensitive indicators of environmental change and stream water quality.
In-stream habitat	Indicators will be developed that characterize the length and percentage of stream habitat condition and the presence of adequate fish cover.
Riparian habitat	The percentage and length of stream miles will be assessed based on condition, as well as the percentage and length of incised stream miles, and those stream lengths with shrub-or-tree-size riparian vegetation.

b. Chemical Stressors that Impact Stream Condition

Various stressors to aquatic ecosystems will be incorporated in the assessment including various measurements of chemical impacts, nutrient concentrations, metals, mine drainage, and salinity (Table 23). These indicators address the Chemical and Physical Characteristics SAB category of analysis (Table 29).

Table 23. Chemical Stressor indicators

Data layer	Data Analysis/Rationale
Chemical	Indicators developed within this category will indicate the percentage and length in miles of streams in each assessment unit that have chemical concentrations greater than state/federal standards and that exceed a threshold of “good” as defined by reference conditions.
Total Organic Carbon	An indicator representing total organic carbon (TOC) as a water quality metric will be developed using a statistical linear regression relationship predicting TOC based on the human land use index, which will be applied spatially to each assessment unit.
Nutrient Concentrations	Indicators for nutrients comprised of total phosphorus and nitrogen are being developed into a data layer. Following methods created for Oregon (Region 10), the phosphorus indicator will be developed using a statistical regression relationship between natural land use/land cover (independent variable) and measured phosphorus concentrations (dependent variable). Spatially applied, this statistical equation will be used to derive a spatial map of entire Region 10 indicating predicted phosphorus, with values ranging from 0 to greater than 0.2 mg/L.
Metals	Indicators for metals are under development.
Acid Mine Drainage	Indicators for acid mine drainage into streams will be developed as a streams layer, which will denote the length and percentage of impacted stream miles within each assessment area.
Stream Salinity	Indicators for stream water salinity are being developed.

c. Biological Stressors

Biological Stressors include exotic or other nuisance fish species, exotic macroinvertebrates, and invasive riparian plants (Table 24). These indicators address the Biotic Condition SAB category of analysis (Table 28).

Table 24. Biological Stressor indicators

Data layer	Data Analysis/Rationale
Exotic/Nuisance Animals	Indicators are being developed to determine the percentage and lengths of streams in miles that have exotic game and nuisance fish species, exotic (nonnative) fish species, and exotic macroinvertebrates.
Invasive Riparian Plants	Indicators will be developed to determine the percentage and lengths of streams in miles in each assessment unit that have invasive riparian plants.

d. Physical Habitat (in- and near-stream) Indicators/Stressors

Physical habitat indicators will include stressors such as excess clean sediment and degree of channelization (Table 25). These indicators address the Hydrology and Geomorphology SAB category of analysis (Table 30).

Table 25. Physical Habitat indicators

Data layer	Data Analysis/Rationale
Excess Clean Sediment	An indicator for excess clean sediment is being developed.
Channelization	Indicators and a data layer will be developed for representing the lengths and percentages of channelized streams within each assessment area.

e. Landscape Condition/Stressors

Landscape models and relevant data will be used to develop various indicators of landscape condition including landscape composition for assessment units, anthropogenic impacts, road densities, and grazing impacts (Table 26). These indicators address the Landscape Condition and Hydrology and Geomorphology SAB categories of analysis (See Table 27 and Table 30).

Table 26. Landscape Condition indicators

Data layer	Data Analysis/Rationale
Landscape Composition	Using landscape models, data layers will be developed to represent the area, percentage of area and distribution of land cover types, agriculture, forest, developed, grasslands, barren land, in each assessment area.
Landscape Anthropogenic Impacts	Indicators will be developed for the location, quantity and percentage of area impacted by anthropogenic impacts within each assessment area including agricultural land uses and urbanization.
Road Density	A road network density landscape metric stressor (km/km ²) with a 3km x 3km pixel size will follow an example from the Colorado Plateau in Utah and Colorado.
Grazing Impacts	An indicator is being developed for grazing impacts along and near riparian habitats.

f. Stressor/Condition Association

The rank order of stressors by frequency that affect aquatic biological resources in each assessment unit will be tabulated. The developed biological and habitat indicators and landscape models can be used to determine associations in each assessment unit between biological integrity of fish assemblages and riparian habitat; between biological integrity of macroinvertebrate assemblages and excess clean sediment; between biological integrity of periphyton assemblages and nutrient loadings; between non-native fish species and biological integrity of fish assemblages; between the integrity of riparian habitat and anthropogenic land cover; and between biological integrity and the percent of public land ownership.

Using the created data layers, landscape models can be created to predict the areas most susceptible in each assessment unit to impact and impairment from grazing, nutrients, excess clean sediments, salinity, and heavy metals. Additionally, percentages of land cover types associated with minimally impacted streams (reference conditions) and streams in poor condition can be determined for each assessment area.

2. Summary of the Region 8 Environmental Monitoring and Assessment Program (EMAP) Water Resources Assessment

The EPA Region 8 Environmental Monitoring and Assessment Program (EMAP) water resources assessment is an ongoing project to compile and analyze available biological monitoring and stressor data to produce a Regional ecological assessment of stream condition within Region 8. Using a condition ranking of good, marginal and poor condition, the assessment is designed to determine the length and location of streams with these conditions; inventory the condition of resources using the same ranking guide; and identify the frequency and magnitude of the stressors impacting resource condition along these streams. Additional goals are to determine the associations between conditions and stressors; predict locations of the condition classes and stressors within each assessment unit. The landscape reporting units for the assessment units in the project are proposed to be 3km and 5km grid cell sizes.

Analysis criteria include various characterizations of ecological conditions of streams and rivers. Criteria are subdivided into groups representing biological and habitat integrity and various stressors. The indicators used in the pilot project include:

- 1) Fish, macroinvertebrate, and periphyton community structures
- 2) Physical habitat (in-stream and near-stream)
- 3) Ambient chemistry (nutrients and major ions)
- 4) Fish tissue (heavy metals and organic contaminants)
- 5) Watershed characteristics

Rankings for condition classes are on a qualitative basis of good, marginal, and poor. Landscape metrics will be used to characterize stressors and stream condition, and stressor association with surface water monitoring sites will be quantified by developing landscape indicators for each catchment/basin, landscape metrics for catchments/basins, and landscape models. Surface water measurements and indicators will be integrated with landscape metrics to produce landscape indicators.

Though the Region 8 project is more specifically focused on water resource assessment and monitoring and the integrity of aquatic biodiversity, its objectives and method development are relevant to the regional identification of critical ecosystems. One of the key features of this project is the linkage of biotic integrity and water quality data collected in the field with landscape models using land cover data and other GIS information. The Region 8 project will likely provide important tools for assessing watershed integrity at regional scales, which will help close an important gap in existing critical ecosystem assessments. One of the future questions for this work is the applicability of landscape indices for aquatic ecosystem integrity developed within the study area to other regions.

G. Region 10 Rapid Access Information System (RAINS)

U.S. Environmental Protection Agency. 2004. Rapid Access Information System (RAINS). Internet application developed by U.S. Environmental Protection Agency, Region 10, Seattle, Washington. Available at the following website: <http://r0drizzle.r10.epa.gov/rains/rains.asp>.

The Rapid Access Information System (RAINS) is an internet application that was developed for the purpose of providing users with quick and easy access to data and information. RAINS allows users to easily locate and display familiar geographical areas and subsequently select and interact with maps for the purpose of displaying and downloading environmental data and information.

1. Application Description

The Rapid Access Information System (RAINS), developed by the U.S. EPA Region 10, is a set of internet applications that combines GIS information with environmental database analytics. It allows users to interactively view, extract, download, and analyze both GIS data and other environmental data. Based on a geographical approach to organizing information, RAINS uses a virtual atlas of known regions and sub-regions that first links users to familiar areas of interest. It then links to additional data and information based on the geographic selections. The RAINS application is built around a combination of pre-processed map images, database tables, structured query language and server scripts that combine to create a virtual atlas of Region 10. Users of RAINS may either connect to libraries of prepared environmental information or use processing applications to adapt the information to specific needs. RAINS also includes links to the following:

- 1) Environmental justice data
- 2) Air quality data
- 3) Impaired waters data
- 4) Salmon species and stock distributions
- 5) Bull trout distributions
- 6) Stream temperatures within watersheds
- 7) Sensitive habitats and species data
- 8) STORET
- 9) National EPA EnviroMapper
- 10) Census TIGER Mapper
- 11) TerraServer Imagery
- 12) TopoZone Imagery
- 13) State environmental mapping websites

ERAINS (Enforcement RAINS) is a sub-system linked to RAINS that includes additional search and display outputs have been added relative to specific detailed regulated facility information and enforcement aspects. An agriculture and forest burn database and weather simulation prediction model, jointly developed with the U.S. Forest Service, may

also be accessed through the system. RAINS may be accessed by EPA users at <http://r0trickle.r10.epa.gov/rains/> or <http://r0drizzle.r10.epa.gov/rains/rains.asp>.

2. Summary of the Region 10 Rapid Access INformation System (RAINS)

RAINS is an intranet/internet data access application that allow users to select a variety of GIS and other data relevant to their area(s) of interest. The system incorporates access to data from a variety of national, regional, and state sources including:

- 1) Environmental justice data
- 2) Air quality data
- 3) Impaired waters data
- 4) Salmon species and stock distributions
- 5) Bull trout distributions
- 6) Stream temperatures within watersheds
- 7) Sensitive habitats and species data
- 8) STORET
- 9) National EPA EnviroMapper
- 10) Census TIGER Mapper
- 11) TerraServer Imagery
- 12) TopoZone Imagery
- 13) State environmental mapping websites

The Region 10 data accessing system could be relevant to organizing and accessing data for critical ecosystem assessments in all regions. The RAINS structure could be used as a template for organizing all relevant GIS data, analytical tools, and internet links to allow users to quickly access all available GIS data, methods and tools relevant to conducting regional-scale critical ecosystem assessments.

H. Commonalities among Region Critical Ecosystem Assessment Projects

1. Input data

The National Land Cover Data (NLCD) is the most important data set used in all of the Regional assessment projects. In fact, this Landsat-based land cover/land use data are the backbone of most analyses done in the Regional assessments. Regions use NLCD to identify coarse classes of upland and wetland natural communities, low intensity land uses, and high intensity land uses in various analyses to address various SAB categories of analysis, especially Landscape Condition and Biotic Condition. Regional assessments also used the NLCD data to address the Chemical and Physical Characteristics (Region 8 models linking land use the Total Organic Carbon) and the Hydrology/Geomorphology categories of analysis.

Region 2, Region 4, Region 5, Region 6, Region 7, and Region 10 have all incorporated listed or imperiled (focal) species occurrence information in some form. However, the data used varied in source, coverage, and resolution. Region 4 obtained species occurrence locations data from only three of the eight state Natural Heritage programs to use in the delineation of the SEF. Region 4 also obtained imperiled and listed species priority areas (summarized by EMAP hexagons), at-risk aquatic species summarized by watersheds and critical watersheds for aquatic biodiversity (using eight-digit HUCs) from NatureServe (Stein et al. 2000). Region 5 used Natural Heritage rare/imperiled species data summarized by 7.5 minute quads for their entire region, which was obtained by working with the 6 state Natural Heritage programs in the Region. Region 6 developed a listed species analysis using federal and state listed species occurrence data from the Texas Parks and Wildlife Department. Region 7 conducted an analysis of rare/imperiled species and endemism using a 1995 Natural Heritage Program data set of species occurrences obtained through agreements with each of the four state Natural Heritage programs.

Region 2, Region 5, Region 6, and Region 10 used STORET (EPA's primary computerized data system) and Toxic Release Inventory Program (TRI) data. Region 5 and Region 6 applied these data to develop several water and air quality analyses. Region 8 is also incorporating various water quality and related data in their assessment of water resources. Region 4 did not use water quality data directly but instead identified a number of national and state designated water bodies identified as having outstanding aquatic resources or resources requiring a certain level of protection.

Region 2 incorporates Wild and Scenic River data and Region 4 also used this data as part of an important water body buffer analysis. Region 2, Region 4, and Region 6 all incorporate FEMA floodplain data. The Region 2 and Region 6 impact assessment applications both use sole source aquifer data.

Region 4, Region 5, Region 6, and Region 8 all incorporate analysis of road densities within their models. Region 4 also includes identification of large roadless areas. All Regions used U.S. Census Bureau TIGER/Line files as the source of road data. Region 2, Region 4, and Region 6 incorporated conservation lands data although from a variety of sources. Finally Region 2 and Region 4 both used some data on from various states identifying environmentally sensitive areas or important wildlife habitats.

2. Tools

All of the Regional assessments used the suite of ESRI GIS software products including ArcView 3.x, Arc-Info, and ArcGIS as the primary GIS analysis tool to conduct most analyses.

3. Analyses

Regions 4, 5, 6, and 7 identify areas containing focal species using Natural Heritage occurrence data. The Natural Heritage ranking system of Global ranks (G ranks) is typically used to either select species occurrences included in the models or to prioritize or weight occurrences. In this ranking system G1 indicates a species that is globally imperiled and G5 indicates a species that is secure or common.

Regions 4, 5, 6, and 7 include similar versions of patch size analyses or fragmentation indices to identify large, intact areas as generally the most ecologically significant or sustainable. Analyses include identifying patches in various size classes or patches that meet a size threshold.

Regions 4, 5, and 6 include analyses of patch shape/fragmentation where patches are either measured using perimeter/area ratios or comparison of patch shape to a circle. Such analyses are useful in combination with patch size and intactness analyses to identify areas less likely to be influenced by negative effects from surrounding land uses (Forman 1995; Farina 1998).

Landscape composition is an important aspect of various analyses in Regions 4, 5, 6, 7, and 8. Analyses often use neighborhood (or shifting-window) algorithms to identify the density of either ecologically-important land cover types such as wetlands or stressors such as urban land uses. Regions 4, 6, and 7 all also include various wetland analyses as a primary modeling component.

Regions 4, 5, and 6 conducted analyses of habitat diversity (Region 6 did so only for wetlands) to identify priority areas and distance from urban land uses as a threat/stressor assessment.

Finally, Regions 4, 5, 6, 7, and 8 all included calculations of road densities as an important indicator of various stressors associated with roads (Trombulak and Frissell 2000; Forman et al. 2003).

I. Unique Regional Assessment Features

1. Unique Data and Analyses

The Regional assessments include many unique data sets or resulting analyses, which are listed below for the assessment projects:

Region 2

The Region 2 impact assessment tool incorporates National Heritage Rivers and National Estuary Program data. It is also unique since it is an internet application, which allows users to identify their area of interest for impact analysis by using onscreen digitizing. The application then identifies environmental features of interest within or near the study area.

Region 4

In the delineation of the Southeastern Ecological Framework (SEF), the Region 4 assessment included several additional national and state datasets as indicators of priority ecological areas. Region 4 identified significant stands of longleaf pine (*Pinus palustris*) and older forest stands of various types from Forest Inventory Assessment from the U.S. Forest Service. Maps of black bear populations (*Ursus americanus*) were the basis for developing a priority potential habitat map for the species (Maehr 1984; Wooding et al. 1994), which also served as a surrogate analysis to identify large, intact habitat blocks for other species of conservation interest (Maehr 2001; Maehr et al. 2002; Hootor 2003). Region 4 incorporated strategic habitats needed to conserve viable populations of focal species delineated by the Florida Fish and Wildlife Conservation Commission. National Estuarine Research Reserves, Wild and Scenic Rivers, Aquatic Preserves, areas with high densities of start stream reaches (Forman 1995), FEMA floodplains, and intact riparian vegetation around all streams were the base for identifying wetland and upland buffers to protect water quality. Region 4 identified priority coastal lands for storm protection with the Coastal Barrier Resources Act lands from FEMA data. To complement road density analyses, Region 4 also identified roadless areas as critical ecosystems due to the importance of the lack of road impacts (Noss and Cooperrider 1994; Trombulak and Frissell 2000; Forman et al. 2003). After identifying priority areas and larger areas of priority areas (Hubs), Region 4 also conducted a landscape connectivity analysis between Hubs using the least cost path function in Arc-Info GRID.

The Region 4 assessment incorporated other unique data and analyses in the Regional prioritization phase that followed delineation of the SEF. DRASTIC data was the input to identify areas most vulnerable to groundwater pollution. Region 4 also buffered ground water and surface water intake points from EPA to coarsely identify potential protection zone priorities. Interior forest analysis was conducted to identify areas potentially most important for supporting forest interior species. Region 4 assessed potential resource-based recreational demand with gravity models based on the influence of population centers, amount of conservation lands, relevant points of interest, and water-based recreation potential. Potential threats from existing and potential future development were characterized using proximity to, and density of, roads and urban land use. Finally, the Region 4 assessment prioritized the Hubs and Linkages within the SEF with a number of content and context analyses that addressed resource significance and ecological integrity.

Region 5

Region 5 applied regionally consistent data in their Critical Ecosystems Assessment Model that included a number of unique elements including appropriate vegetation analysis, aquatic ecosystem fragmentation, and various stressor analyses. Region 5 used climate data to identify areas with the highest average daily temperature and daily precipitation. Region 5 combined Kuchler Potential Natural Vegetation and a digital elevation model (DEM) to develop an analysis comparing existing land cover to potential natural vegetation where land cover that matched the appropriate potential natural vegetation class was given higher priority. Region 5 also analyzed land cover rarity for each ecoregion to identify rarer land cover types as higher priorities. Region 5 conducted analyses of water bodies and watersheds impacted by dams as a stressor/threat

analysis. Other unique stressor/threat analyses in the Region 5 analysis include: airport noise, Superfund sites, and hazardous waste cleanup sites.

Region 6

The Region 6 assessment model includes many unique indices relevant to identifying/prioritizing areas based on their ecological significance. Unique water quality analyses/indices include: surface waters supporting their designated use, surface water quantity, distance to surface water, ground water probability and quality, unified watershed and clean water act state priority data, average stream flow, sole source aquifer data, channelization, individual well water sources, septic tank and cesspool use, and soil permeability. Ecological analyses/indicators include: an agricultural lands index (where higher percentages of agricultural lands were given a higher priority to indicate the potential for farmland loss), an NLCD-based index of wildlife habitat and wildlife habitat quality, landscape texture and aggregation measures (relevant to fragmentation), Endangered Species Act compliance data, and percent of watershed/geographic area occupied by potential polluting facilities. Region 6 also created indicators for air quality based on ozone nonattainment data, and developed a unique potential stressor assessment to address concentrated animal feeding operations (CAFO). Finally, as part of their assessment model for environmental impacts Region 6 incorporated many socioeconomic criteria to address potential environmental justice and related issues.

Region 7

Region 7 assessment developed several unique analyses based on NLCD and other data to identify basins with higher priority wetlands. Region 7 calculated agricultural land use density where basins with more agriculture were given lower priority due to the potential for wetland impacts. Region 7 conducted an endemism analysis where basins containing species found in only in one or a few basins were given higher priority. A mean distance between wetland analysis prioritized basins that had lower mean distances. Finally, the Region 7 assessment used principal components analysis to create a wetland priority index with a combined ranking based on the rarity (level of imperilment) of species and habitat quality within each basin.

Region 8

The Region 8 assessment is still in progress with most analyses not completed. The key unique feature of this project is the linkage of biotic integrity and water quality data collected in the field with landscape models using land cover data and other GIS information. Specific analyses include land cover/land use based indicators of total organic carbon, phosphorous, and nitrogen.

Region 10

The Region 10 RAINS is a data organization and accessing tool that significantly enhances access to a variety of national, regional, and state data sets that can be used to identify critical ecosystems or to conduct environmental impact assessments.

2. Unique Tools

Region 4 used ERDAS Imagine to conduct parts of the urban growth potential analysis. Region 5 used the Analytical Tools Interface for Landscape Assessments (ATtILA) Version 3.0 landscape tool to calculate land cover diversity. Region 6 used the APACK software program, which is an alternative to Fragstats for calculating various landscape metrics, to calculate several indices including landscape texture and landscape aggregation. Region 7 used Fragstats 3.3 to calculate wetland density, wetland habitat diversity, mean distance between wetlands, and wetland patch size. ATtILA, APACK, and Fragstats are described in Appendix B.

J. Addressing SAB Framework Essential Ecological Attributes

Collectively the Regional assessments analyses address many of the SAB reporting categories (Table 27-Table 30). All five of the Regional critical ecosystem assessment projects (Region 4, Region 5, Region 6, Region 7, and Region 8) address the three reporting categories (extent of ecological system/habitat types, landscape composition, and landscape pattern and structure) for the SAB Landscape Condition EEA. In general, all of the assessments also address the ecosystems/communities and the species/populations reporting categories for the Biotic Condition EEA. Three of the regions (Region 5, Region 6, and Region 8) collectively address various aspects of the nutrient concentrations, trace inorganic and organic chemicals, other chemical parameters, and physical parameters reporting categories for the Chemical and Physical Characteristics EEA. Region 4, Region 5, Region 6, and Region 8 potentially address the dynamic structural characteristics reporting category for the Hydrology/Geomorphology EEA.

K. Categories of Analysis Not Addressed in the Assessments Collectively

Few categories of analysis from the SAB Framework for Assessing and Reporting on Ecological Condition were not addressed in some way by the Regional assessments (Table 27-30). However, two of the SAB categories, Ecological Processes and Natural Disturbance Regimes, are not addressed directly by any of the Regional assessments (Table 30). Others that are only marginally addressed include the organism condition reporting category under the Biotic Condition EEA and the surface and groundwater flows and sediment and material transport reporting categories under the Hydrology and Geomorphology EEA (See Table 28 and Table 30). Finally, all of the reporting categories under Chemical and Physical Characteristics EEA are addressed by several of the Regional assessments but not all (Table 29). There are at least three primary reasons for these gaps in analysis: 1) appropriateness of the SAB Framework for assessments of critical ecosystems versus reporting on ecological condition or ecological monitoring; 2) purpose and goals of the various assessments; 3) difficulty in matching various analyses in the Regional assessments to SAB categories. These issues will be examined further in the discussion section below.

Table 27. Regional analyses that address the Landscape Condition category of analysis

SAB Reporting Categories and U.S. EPA Region Analyses					
SAB Reporting Categories	Region 4- Southeastern Ecological Framework (SEF)	Region 5- Critical Ecosystems Assessment Model (CrEAM)	Region 6- GIS Screening Tool (GISST)	Region 7- Synoptic Assessment of Wetland Function	Region 8- Environmental Monitoring and Assessment Program (EMAP) Assessment
Landscape Condition					
Extent of Ecological System/Habitat Types	PEAs--Roadless Areas	Diversity Criterion- Contiguous sizes of undeveloped areas data layer	Ecological Criterion- Patch area (normalized, averaged) data layer	Index 2 (Habitat Quality)- Mean wetland patch size data layer	In-stream habitat
	Identification of Hubs--areas of high ecological significance 2,000 hectare and larger	Self Sustainability (Fragmentation) Criterion- Contiguous sizes of individual land cover types data layer	Ecological Criterion- Habitat fragmentation data layer	Index 3 (Species Sensitivity)- Habitat quality categorical modifier to the global rarity score data layer	Riparian habitat
	Prioritization-- Conservation Lands Size Classes and Proximity				
	Prioritization-- Size Classification of Priority Ecological Area after Exclusion				
Landscape Composition	PEAs--Areas of high habitat diversity	Diversity Criterion- Land cover diversity by ecoregion data layer	Ecological Criterion- Landscape texture data layer	Index 1 (Habitat Quality)- Agricultural density data layer	Land cover types
	PEAs--Existing public conservation lands and private preserves	Diversity Criterion- Temperature and precipitation by ecoregion data layer	Ecological Criterion- Wildlife habitat data layer	Index 1 (Habitat Quality)- Wetland density data layer	Road network density
	PEAs--Proposed public conservation lands (Florida only)	Diversity Criterion- Appropriateness of land cover (using Kuchler) data layer	Ecological Criterion- Agricultural lands	Index 2 (Habitat Quality)- Agricultural density data layer	

Table 27 continued. Regional analyses that address the Landscape Condition category of analysis

Landscape Composition continued	PEAs--North Carolina land trust priority areas	Self Sustainability (Fragmentation) Criterion - Appropriateness of land cover (using Kuchler) data layer	Ecological Criterion- Wetlands	Index 2 (Habitat Quality)- Wetland density data layer	
	Exclusion--Road density		Ecological Criterion- Road density	Index 2 (Habitat Quality)- Wetland habitat diversity data layer	
	Exclusion--Urban density		Ecological Criterion- Density of managed lands	Index 2 (Habitat Quality)- Mean distance between wetland patches data layer	
	Prioritization-- Topographic Diversity within Hubs			Index 3 (Species Sensitivity)- Habitat quality categorical modifier to the global rarity score data layer	
	Prioritization-- Percent Wetlands per Hub				
	Prioritization-- Interior Forests				
Landscape Pattern and Structure	PEAs-- Significant natural edge habitat	Self Sustainability (Fragmentation) Criterion - Area/Perimeter ratio data layer	Ecological Criterion- Landscape aggregation data layer	Index 1 (Habitat Quality)- Agricultural density data layer	Land cover types
	PEAs--Roadless areas	Self Sustainability (Fragmentation) Criterion – Road density	Ecological Criterion- Road density	Index 1 (Habitat Quality)- Wetland density data layer	Road network density
	Identification of landscape linkages between upland/wetland Hubs			Index 2 (Habitat Quality)- Agricultural density data layer	
	Identification of landscape linkages along riparian ecosystems			Index 2 (Habitat Quality)- Wetland density data layer	
	Identification of landscape linkages between upland Hubs			Index 2 (Habitat Quality)- Mean distance between wetland patches data layer	

Table 27 continued. Regional analyses that address the Landscape Condition category of analysis

Landscape Pattern and Structure continued	Exclusion--Road density			Index 3 (Species Sensitivity)-Habitat quality categorical modifier to the global rarity score data layer	
	Exclusion--Urban density				
	Prioritization--Spatial Mix of Wetlands and Uplands within Hubs				
	Prioritization--Size & Proximity to Wetlands				
	Prioritization--Landscape Viability Index				
	Prioritization--Urban Growth Potential Model				

Table 28. Regional analyses that address the Biotic Condition category of analysis

U.S. EPA Regions Data and Analyses					
SAB Reporting Categories	Region 4- Southeastern Ecological Framework (SEF)	Region 5- Critical Ecosystems Assessment Model (CrEAM)	Region 6- GIS Screening Tool (GISST)	Region 7- Synoptic Assessment of Wetland Function	Region 8- Environmental Monitoring and Assessment Program (EMAP) Assessment
Biotic Condition					
Ecosystems and Communities	PEAS--Wetlands	Rarity Criterion- Land cover rarity by ecoregion data layer	Ecological Criterion- Wetlands	Index 1 (Habitat Quality)- Wetland density data layer	In-stream habitat
	PEAs--Areas with significant longleaf pine stands	Rarity Criterion- natural community rarity per 7.5 minute quad data layer	Ecological Criterion- Ecologically significant stream segments	Index 2 (Habitat Quality)- Wetland density data layer	Riparian habitat
	PEAs--Old growth forest stands	Diversity Criterion- Appropriateness of land cover (using Kuchler) data layer	Ecological Criterion- Wildlife habitat	Index 2 (Habitat Quality)- Wetland habitat diversity data layer	
	PEAs--Lands identified as part of the Coastal Barrier Resources Act		Ecological Criterion- Wildlife habitat quality	Index 2 (Habitat Quality)- Mean wetland patch size data layer	
	PEAs—Various designated water bodies and buffers delineated to protect hydrology			Index 3 (Species Sensitivity)- Habitat quality categorical modifier to the global rarity score data layer	
	PEAs--Element occurrence data for rare natural communities (Alabama, Georgia, and Florida only)				
	PEAs--Significant natural communities (Florida and North Carolina only)				
	PEAs--Significant riparian habitat				
	Prioritization--Size & Proximity to Wetlands				

Table 28 continued. Regional analyses that address the Biotic Condition category of analysis

Ecosystems and Communities continued	Prioritization--Interior Forests				
Species and Populations	PEAs--Potential black bear habitat	Rarity Criterion- Species rarity per 7.5 minute quad data layer	Ecological Criterion- Federal and state listed species presence	Index 1 (Habitat Quality)- Global rarity score data layer	Fish assemblages
	PEAs--Element Occurrence data for rare/imperiled species (3 states only)	Rarity Criterion- Number of rare species per 7.5 minute quad data layer	Ecological Criterion- Wildlife habitat	Index 1 (Habitat Quality)- Endemism data layer	Macroinvertebrate assemblages
	PEAs--Florida Strategic Habitat Conservation Areas	Rarity Criterion- Number of rare taxa per 7.5 minute quad data layer	Ecological Criterion- Wildlife habitat quality	Index 2 (Habitat Quality)- Global rarity score data layer	Periphyton assemblages
	PEAs--Florida vertebrate species hotspots		Ecological Criterion- Ecologically significant stream segments	Index 2 (Habitat Quality)- Endemism data layer	Exotic game and nuisance fish species
	PEAs--North Carolina Coastal Fish Nursery Areas			Index 3 (Species Sensitivity)- Global rarity score data layer	Exotic (nonnative) fish species
	PEAs--North Carolina Anadromous Fish Spawning Areas			Index 3 (Species Sensitivity)- Endemism data layer	Exotic macroinvertebrates
	Prioritization--Interior Forests				
	Prioritization--Imperiled Species Priority Areas				
	Prioritization--Listed Species Priority Areas				
	Prioritization--At-Risk Aquatic Species by Watersheds				
	Prioritization--Critical Watersheds for Aquatic Biodiversity				
	Prioritization--Black Bear Habitat Suitability Analysis				

Table 28 continued. Regional analyses that address the Biotic Condition category of analysis

Organism Condition					Fish assemblages
					Macroinvertebrate assemblages
					Periphyton assemblages

Table 29. Regional analyses that address the Chemical and Physical Characteristics category of analysis

SAB Reporting Categories and U.S. EPA Region Analyses					
SAB Reporting Categories	Region 4- Southeastern Ecological Framework (SEF)	Region 5- Critical Ecosystems Assessment Model (CrEAM)	Region 6- GIS Screening Tool (GISST)	Region 7- Synoptic Assessment of Wetland Function	Region 8- Environmental Monitoring and Assessment Program (EMAP) Assessment
Chemical and Physical Characteristics (Water, Air, Soil, and Sediment)					
Nutrient Concentrations		Self Sustainability (Stressors) Criterion- Water quality (BASINS model summary) data layer	Water Quality Criterion- Water quality (Storet Data) data layer		Total organic carbon
					Nutrients (phosphorus and nitrogen)
Trace Inorganic and Organic Chemicals		Self Sustainability (Stressors) Criterion- Air quality (from OPPT air risk model) data layer	Air Quality Criterion-Air quality		Metals
			Toxicity Criterion		Acid mine drainage
Other Chemical Parameters		Self Sustainability (Stressors) Criterion- Water quality (BASINS model summary) data layer			Stream water salinity
Physical Parameters		Self Sustainability (Stressors) Criterion- Air quality (from OPPT air risk model) data layer	Water Quality Criterion- Aquifer/geology rating data layer		
		Self Sustainability (Stressors) Criterion- Water quality (BASINS model summary) data layer	Water Quality Criterion- Soil permeability data layer		

Table 30. Regional analyses that address the Ecological Process, Hydrology and Geomorphology, and Natural Disturbance categories of analysis

SAB Reporting Categories and U.S. EPA Region Analyses					
SAB Reporting Categories	Region 4- Southeastern Ecological Framework (SEF)	Region 5- Critical Ecosystems Assessment Model (CrEAM)	Region 6- GIS Screening Tool (GISST)	Region 7- Synoptic Assessment of Wetland Function	Region 8- Environmental Monitoring and Assessment Program (EMAP) Assessment
Ecological Processes					
Energy Flow					
Material Flow					
Hydrology and Geomorphology					
Surface and Groundwater Flows	Prioritization-- Surficial Aquifer Areas Vulnerable to Pollution?				
	Prioritization-- Surface Water Source Priorities?				
	Prioritization-- Ground Water Source Priorities?				
Dynamic Structural Characteristics	PEAs--Forest areas with high stream start reach densities	Self Sustainability (Fragmentation) Criterion- Waterway impoundments per waterbody data layer	Water Quality Criterion- Surface water quantity data layer		Channelized streams
	PEAs--North Carolina Coastal Fish Nursery Areas	Self Sustainability (Stressors) Criterion- Waterway obstructions (dams per HUC) data layer	Water Quality Criterion- Channelization?		Grazing impacts
	PEAs--North Carolina Anadromous Fish Spawning Areas				
	PEAs-- Significant riparian habitat				
	PEAs--Lands identified as part of the Coastal Barrier Resources Act				
	Identification of landscape linkages/buffers along riparian ecosystems				

Table 30 continued. Regional analyses that address the Ecological Process, Hydrology and Geomorphology, and Natural Disturbance categories of analysis

Dynamic Structural Characteristics continued	Identification of landscape linkages/buffers along riparian ecosystems				
	Prioritization-- Size & Proximity to Wetlands				
	Prioritization-- Major and Wild and Scenic River Buffers				
	Prioritization-- Coastal Storm Protection Areas				
	Prioritization-- Number of Stream Start Reaches per Hub				
Sediment and Material Transport					Excess clean sediment
Natural Disturbance Regimes					
Frequency					
Intensity					
Extent					
Duration					

IV. Discussion

All of the EPA Regional assessments were conducted with different goals using various data and methods. The Region 2 project provides an internet-based impact screening tool that incorporates a number of GIS datasets relevant to identifying critical ecosystems. The Region 4 and Region 5 models are the most similar and most directly address the issue of identifying critical ecosystems. The Region 6 project is a very detailed impact assessment model with a number of component analyses that are relevant to the identification of critical ecosystems. The Region 7 model has the very specific goal of identifying basins that are the highest priority for wetland protection, but this assessment also developed analyses that can be used to identify critical ecosystems. The Region 8 project is more specifically focused on water resource assessment and monitoring and the ecological integrity of aquatic biodiversity. The project includes elements that are relevant to closing gaps in aquatic resource assessments. The Region 10 data system could be relevant to organizing and accessing data for critical ecosystem assessments in all regions.

Another important comparison of the Regional assessment projects is the scale, or resolution, of analysis. First, individual grid cells (pixels) can be, and are, used in assessments of critical ecosystems when data resolution allows. Examples include an output resolution in the Region 4 analysis of 90 meter grid cells and a 300 meter grid cell output resolution in Region 5. Second, summarizing by selection units (such as watersheds) is another method conducted based on either the goals of the assessment or the input data and types of analyses that require selection units to address data resolution or analytical issues. The Region 7 wetlands prioritization used sub-basins (delineated by US Geological Survey eight-digit Hydrologic Unit Codes) to identify watersheds where conservation action would be expected to have the most benefits for wetland biodiversity.

Though one obvious goal of GIS assessments is for results to have as high a resolution as possible, both assessment scales can be important to make the best use of available data and analytical tools. Though more spatially specific approaches may be preferred when feasible, both approaches provide benefits for regional-scale assessments of critical ecosystems and are potentially complementary. The primary reason for the utility of both approaches is that many available GIS data and analytical methods lend themselves to the development of summary statistics for larger geographic units versus more specific identification of areas of significance. For example, indices such as mean patch sizes and mean distance between patches are at least more easily applied to summary geographic units than to pixel-based approaches. As noted by the authors of the Region 7 synoptic wetland assessment, these approaches can be complementary. Larger geographic units can be used where appropriate to summarize data and utilize methods difficult to apply to more spatially-explicit approaches in order to prioritize them. More spatially explicit approaches can then be used to identify the specific areas of ecological significance within higher priority geographic units and to also identify specific areas within lower priority geographic units that are also worthy of conservation attention.

Current Regional assessments address the primary categories of analysis for identifying critical ecosystems, but they do not address all SAB Framework categories or other analysis categories that could be incorporated. Some of the SAB categories are

more applicable to local-scale monitoring and are either impossible or very difficult to address at regional scales (See Young and Sanzone 2002; pp. 21-22).

The identification of critical ecosystems is an extension of reserve design, which strictly defined is the science and art of identifying and designing the areas needed to effectively conserve biodiversity (Harris 1984; Noss and Cooperrider 1994; Noss 1996; Margules and Pressey 2000). In the case of critical ecosystems and EPA mandates, the protection of ecosystem services, the goods and services provided by natural/semi-natural lands and waters, is also paramount (Daily 1997; Daily 2000; Pimentel et al. 2000).

The identification of stressors is also important. First, the absence, or low-level, of stressors can be taken as a sign that an area may still have at least relatively high ecological integrity. This would include areas with no roads or low road densities, distant from urban land uses, at least largely free of various forms of pollutions, and not dominated or significantly impacted by invasive species (Noss and Cooperrider 1994; Noss et al. 1999; Groves et al. 2000). Second, stressors can be useful for identifying where priority ecological resources are threatened by inappropriate activities or conditions. For example, watersheds that are critical for aquatic biodiversity but are also threatened by pollution or other stressors are a high priority for threat abatement (Stein et al. 2000).

In the following sections on opportunities and obstacles, the discussion is organized either by SAB Framework Essential Ecological Attributes or the individual reporting categories in a manner that makes the most sense for critical ecosystem assessments. For example, the discussion of the Landscapes EEA does not refer to the individual reporting categories (extent, composition, pattern and structure) since these reporting categories are often combined when identifying critical ecosystems. We discuss the protection of water and air resources within a combined discussion of the Chemical and Physical and Hydrology and Geomorphology Attributes. We discuss stressors where they are relevant to specific analyses addressing various categories of analysis.

A. Opportunities and Challenges

Although almost all of the Regional projects described and analyzed in this report were created to address different purposes, there is a common framework regarding input data, tools, and analytical methodologies that provides a strong foundation for sharing information to conduct significantly enhanced Regional critical ecosystem assessments in the future. The National Land Cover Data (NLCD) is a primary component of all existing Regional projects, many Regions use Natural Heritage occurrence data to identify areas important for protecting focal species, and all Regions use road data to assess issues associated with high road densities. All Regions use ESRI GIS software products as the primary tool for conducting analyses, so sharing methods for addressing aspects of critical ecosystem identification should be relatively straightforward for all analyses using ESRI software.

Obstacles include various data and some tool and analysis issues. Primary data issues include the timeliness and classification detail of the NLCD, the consistent availability of Natural Heritage data for all Regions, and lack of more specific information to identify habitat needed to conserve viable populations of focal species and functional landscapes to protect biodiversity and provide ecosystem services.

Not all analyses can be done, or at least easily accomplished, using ESRI ArcGIS, ArcView, or ArcInfo. Some regions have used other analytical tools as alternatives including the Analytical Tools Interface for Landscape Assessments (ATtILA) Version 3.0, Fragstats 3.3 habitat fragmentation and landscape analysis software, and the APACK software program, which is a potential alternative to Fragstats for calculating various landscape metrics. Fragstats can calculate a wide variety of potential fragmentation and landscape metrics but is generally not capable of handling the processing requirements of regional-scale analyses. APACK may be a viable alternative to Fragstats for calculating landscape metrics at regional scales but more information is needed about the software including potential interface or transferability with ESRI GIS software. Sharing information between regions about these tools regarding their analytical capabilities and possibly standardizing (or at least increasing the accessibility) the use of certain tools for conducting specific analyses would be useful.

The development of assessment methods to identify areas important for protecting, or restoring, ecosystem services is a primary analysis issue. In particular, data and quantitative assessments of areas important for flood control/abatement, protecting water quality for drinking water sources and other purposes, and areas important for abating air pollution including carbon sequestration are all important gaps in current critical ecosystem assessments. Furthermore, although Regions address biodiversity in a number of ways in all of the Regional projects, the science and art of “reserve design” continues to grow within the discipline of conservation biology (Harris 1984; Noss and Cooperrider 1994; Harris et al. 1996b; Barrett and Barrett 1997; Soulé and Terborgh 1999; Margules and Pressey 2000; Groves et al. 2003; Noss 2003). Reserve design can include detailed analyses of landscapes, natural communities, and species that require more specific data and can be very time intensive. Therefore, one of the important issues for regional-scale assessments of critical ecosystems is the acquisition of data and development of methodologies that address these aspects of reserve design to the extent practicable, and/or development of valid surrogate analyses to identify areas needed to protect biodiversity (which has been done in most of the existing Regional projects), and/or development of partnerships with other agencies and organizations to share their expertise and their existing assessments of biodiversity. Finally, methods of selecting criteria for determining ecological significance and sensitivity analyses are important issues that should be addressed in future Regional critical ecosystem assessments.

We address all of these issues in more detail in the following sections, which discuss the various categories of analysis that should be incorporated into regional-scale critical ecosystem assessments. Table 31 includes the categories of analysis and indicates whether these are addressed in current Regional analyses and therefore also summarizes suggestions for improving future efforts for identifying critical ecosystems at regional scales. This table is intended to show what the Regional projects address regarding various critical ecosystem analyses to serve as an indicator of what could be done in future assessments. It must be noted that these projects were not all designed to specifically identify critical ecosystems are all aspects of critical ecosystems, and other aspects of critical ecosystem assessment may be addressed in other currently ongoing efforts within Regions. Therefore, gaps in the analyses included in this table do not indicate relative importance or quality of a project or represent all research efforts that may be ongoing within various Regions.

1. Landscapes

The Regional assessments and other work use current data to address the landscape category in a variety of ways. However, more work is needed on how to define and identify “functional landscapes”, meaning areas that are large enough with sufficient ecological integrity to maintain biodiversity and key ecosystem services (Harris et al. 1996a; Noss et al. 1999; Pimentel et al. 2000; Poiani et al. 2000). Based on existing projects and reserve design practice, identifying significant landscapes can include:

- 1) Identifying large roadless areas with natural/semi-natural land cover.
- 2) Identifying large areas with a lack, or low level of various stressors including roads and intensive land use.
- 3) Identifying areas with large percentages or density of existing public conservation lands (and private preserves).
- 4) Identifying areas with high habitat, natural community, or physical habitat diversity.
- 5) Identifying large patches of natural/semi-natural lands or specific natural communities or ecosystem types.
- 6) Identifying patches with more appropriate shapes to avoid negative external influences.
- 7) Identifying areas with no or little fragmentation or high densities of natural communities.
- 8) Identifying areas with significant interior habitat.
- 9) Identifying areas with habitat/natural community patches in close proximity.
- 10) Identifying areas important for maintaining or restoring landscape connectivity.

Many of these analyses have been handled in existing Regional critical ecosystem assessments (Table 31). Other sources of data that could be used to enhance existing assessments in all Regions include a national forest intactness analyses (Heilman et al. 2002; Riitters et al. 2002), a national conservation lands database (DellaSala et al. 2001), and TNC ecoregional plans that include identification of large, intact areas (Groves et al. 2000; Groves et al. 2002; Groves et al. 2003). Various landscape ecology texts also provide discussions of landscape metrics that can either be run in ESRI ArcGIS or by using landscape metric software such as APACK or Fragstats (Farina 1998; Turner et al. 2001). See Appendix B for more information on APACK and Fragstats.

The primary obstacle for landscape analyses is the availability of current land cover/land use data at the national scale. The current NLCD data are over 10 years old and indications are that a new version will not be complete at least until 2006. If so, the new version will already be out-of-date by approximately five years. It is critical that a national land cover/land use dataset be updated on a regular basis and be maintained with the highest available standards. Projected enhancements in the new version of NLCD sound promising, but it is also imperative that a dataset be released that is timely (e.g., close to the date of the imagery it is based on) and is updated regularly with at least new versions no more than ten years apart and preferably every five years. This is especially important in high growth regions. It is possible to develop good classifications of Landsat imagery relatively quickly. For instance, the Florida Fish and Wildlife Conservation Commission has just released a new land cover/land use dataset for Florida

that is based on 2002-2003 Landsat imagery, which will be used to update their various species habitat models (Cox et al. 1994; Cox and Kautz 2000; Kautz and Cox 2001).

2. Natural communities/ecosystems

Existing regional projects address natural communities in several ways that address many aspects of identifying areas containing important natural communities (Table 31). However, recent developments in reserve design include more complicated methodologies including representation, or irreplaceability, analyses. Natural communities/ecosystems can be addressed in several ways using current data:

- 1) Identifying rare or imperiled natural communities using Natural Heritage occurrence data.
- 2) Identifying important matrix (communities that are the dominant land cover in a landscape or region) communities or ecoregion-specific “appropriate” land cover including use of potential natural vegetation information.
- 3) Identifying other important natural communities using representation or similar analyses.

Availability of natural community data is an important issue. First, Natural Heritage natural community occurrences have not been made available in all cases in all regions. EPA has been working with NatureServe, the association for the state Natural Heritage programs, to make Natural Heritage data available for EPA uses but it has yet to happen for the entire nation. If this occurs, whether the actual occurrence locations or a summarized/generalized form of the data (such as by quads) are made available is another issue. However, Region 7 provides an example of how this could work to procure detailed Natural Heritage Data for all Regions. First, for the wetland assessment tool, Region 7 obtained Natural Heritage occurrence data through agreements with each of their state Natural Heritage programs for the 1995 data set. More recently, Region 7 obtained a 2003 occurrence data set for all 4 states through an agreement with NatureServe. Region 7 obtained licenses only for the data sets and thus the data itself remains the property of the provider and not subject to Freedom of Information Act (FOIA), which included an agreement in the licenses to generalize the locational information in any product designed for public disclosure.

Another important obstacle is the coarseness of the NLCD regarding natural community classification. Representation analysis is an important, and increasingly sophisticated, part of biodiversity reserve design processes (Noss 1996; Groves et al. 2002). Representation simply means assessing the level of protection of certain resources compared to a goal. The most common form of representation analysis is to compare natural communities from land cover data with existing conservation areas to determine which natural communities are adequately protected versus ones that are not. However, in many cases regional-scale land cover classifications are not adequately resolute to conduct meaningful representation analysis, which is the case with NLCD data. There are several options for addressing this gap in current analyses. As part of The Nature Conservancy’s ecoregional planning process, a physical habitat classification system was developed to overcome this issue in some ecoregions. Such physical habitat models can be built with available data including basic land cover, soils or surficial geology, and

digital elevation models (Groves et al. 2000; Noss et al. 1999b; Noss et al. 2002). Most of these data are currently available nationally including the availability of specific soils data (SSURGO) in the near future. Another option is to conduct representation analysis using Natural Heritage natural community occurrences if they are available instead of land cover data. Where available, land cover data from the USGS GAP Analysis program are typically sufficiently detailed to conduct a basic representation analysis, and the developing multi-state GAP projects for the southwest and southeast US may provide more detailed land cover data at regional scales (See Appendix B for more information on GAP).

To aid with representation analysis in ecoregional planning, The Nature Conservancy also worked with partners at the University of California-Santa Barbara to develop a user-friendly ArcView extension called SITES (Andelman et al. 1999). This extension can be used to conduct traditional natural community representation analysis and to identify the minimum set of areas needed to meet set conservation goals. SITES is based on a program called Spexan, which is a reserve design efficiency algorithm. Efficiency algorithms help determine what areas can best address the set conservation goals in the smallest area or for the smallest cost possible. There is now a new version of Spexan called Marxan with various improvements (Ball 2000; Ball and Possingham 2000), although the Spexan-based SITES ArcView extension can still be used. Marxan was recently applied to assess various GIS data layers representing goals for the Florida Forever land acquisition program to determine which areas would best meet these goals given current program funding levels (Oetting and Knight 2004). Both Spexan/SITES and Marxan have now been applied to various other applications as well (Ardron et al. 2002; Kelley et al. 2002; Leslie et al. 2003; Noss et al. 2002). However, it is important to point out that these efficiency algorithms do not address landscape considerations and especially connectivity (Briers 2002).

Region 7 is currently working on a project to identify critical ecosystems in terrestrial and aquatic environments. In this effort, Region 7 reviewed the SITES/Spexan/Marxan software but decided to use an alternative tool, named C-Plan, to develop an irreplaceability analysis targeting both landscape and biological variables (Ferrier et al. 2000; Pressey et al. 2003). Irreplaceability is an important aspect of representation analysis, which determines how essential an area is for representing unique elements of a region's biodiversity. Region 7 expects to have two pilot ecoregions completed by the end of September 2004 and will complete the entire region by September 2005.

3. Species

Species analyses relevant to the identification of critical ecosystems can range from relatively simple to extremely complex. In an ideal analysis, habitat and viability risk assessments would be done for all species of conservation interest (focal species). This process would involve the development of habitat maps for each species and then the use of viability models to determine how much habitat (and potentially in what spatial arrangement in spatially-explicit viability models) is necessary to maintain viable populations. The Florida Fish and Wildlife Conservation Commission developed the best example of this kind of assessment, which included detailed habitat assessments for dozens of focal species to identify strategic areas for maintaining viable populations (Cox

et al. 1994; Cox and Kautz 2000; Kautz and Cox 2001). Existing requirements for each state to develop wildlife conservation plans in order to access federal conservation dollars may result in similar work in additional states.

Given that the development of such species models for all, or even most, species of conservation interest is unlikely in EPA Regional assessments of critical ecosystems or in other assessments, there are several options for addressing species conservation needs. First, relying on existing analyses or working with partners such as the state's with their wildlife conservation strategies or NGO planning processes should be considered. For instance, The Nature Conservancy's ecoregional plans are either completed, or will soon be completed, for all U.S. ecoregions (Groves et al. 2000; Groves et al. 2002). Though the details of each plan vary, the goal is to identify all sites and actions needed to effectively protect biodiversity in each region. These plans include both species and natural community assessments, and landscape-level analyses are also often conducted as well. In addition, the federal Wildlife and Conservation Restoration Act established the State Wildlife Grants program, which was created to provide federal financial assistance to states for the development, revision, and implementation of wildlife conservation strategies to prevent species and habitats from becoming endangered. In order to be eligible for State Wildlife Grants each state is required to develop a wildlife conservation strategy to be completed by October 2005, and these strategies should result in the identification of areas needed to conserve various focal species.

Another option is to develop habitat models and possibly viability assessments for well-selected umbrella or indicator species. Although such assessments can never capture the habitat needs of all species (Caro and O'Doherty 1999), they can serve to identify habitat conservation needs for many species (Lambeck 1997). Habitat models include simple Boolean models (areas are identified as habitat or non-habitat), ranges of rules-based index values, or more complex statistical techniques such as multiple logistic regression (Cox et al. 1994; Mladenoff et al. 1995; Mladenoff and Sickley 1998; Carroll et al. 1999; Mladenoff et al. 1999; Cox and Kautz 2000; Carroll et al. 2001; Kautz and Cox 2001; Noss et al. 2002; Scott et al. 2002; Hctor 2003). USGS GAP analysis project models and the models created by the Florida Fish and Wildlife Conservation Commission are good guides for developing relatively simple habitat models (Scott et al. 1993; Cox et al. 1994; Cox and Kautz 2000; Kautz and Cox 2001; Scott et al. 2002).

In lieu of, or to complement, species habitat models, Natural Heritage species occurrence from NatureServe and its partner programs can be used in a variety of ways to identify areas important for listed or imperiled species. In fact, these data are the most complete documentation of known locations of focal species, and are an important building block for identifying critical ecosystems. As with the Natural Heritage natural community data, EPA needs to pursue a working agreement with NatureServe to make such data available for EPA work while protecting the integrity of the data. Species occurrence data can be used to simply select areas containing listed or imperiled species, to identify areas with high densities of species locations, or to give higher priority to areas containing more species with higher imperilment rankings, which have all been done in some form in current Regional analyses where such data were available. Furthermore, representation or irreplaceability analysis can also be used to assess areas that best protect known species locations. Such analyses typically include a goal to include a

certain number of occurrences for each focal species to increase the likelihood that each species will remain viable within the study area (Groves et al. 2002; Groves et al. 2003).

Population viability analysis is a much more sophisticated alternative to representation analysis of species occurrences or depictions of potential habitat. Though population viability, or risk, assessments for species are much more time consuming and require at least fairly detailed demographic data, they can help identify how much habitat needs to be conserved or even where the most important habitat is for maintaining viable populations. There are several existing software packages that can be used. VORTEX is a non-spatially explicit model used in many viability assessments (Lacey 1993). However, spatially explicit viability assessment software has been developed within the last five years and is increasingly used. The two primary options are RAMAS GIS and PATCH (Schumaker 1998; Carroll et al. 2003; Akçakaya et al. 2004; Carroll et al. 2004). Both software packages will determine whether a population or metapopulation (a set of demographically or genetically connected populations) is viable and what areas are most important for maintaining viable populations. Though such models are labor intensive, they could be applied to at least a few selected focal species in critical ecosystem assessments when time and expertise allow.

Another additional important data source is designated critical habitat for federal endangered and threatened species. Critical habitat is somewhat similar to the results of viability assessments since critical habitat is intended to include the areas needed to at least successfully maintain, or hopefully recover, each federally listed species. Currently there is not a national GIS database of critical habitat. EPA should discuss this issue with the U.S. Fish and Wildlife Service to determine whether such a database could be developed and then used in critical ecosystem assessments and other EPA programs.

Data and ecological characteristics for aquatic species are sufficiently different from terrestrial species to require special assessments. GAP analysis and TNC ecoregional planning have both been evolving to incorporate detailed aquatic species assessment. Data include information on distributions and occurrences of aquatic species, physical habitat classifications to delineate representation requirements, and evaluation of water quality and watershed threats. Appendix B includes one example of such an assessment conducted by the Missouri Resource Assessment Partnership (MoRAP).

Identifying areas where habitat restoration is important is another consideration. Assessments of existing habitat and the biological requirement of a species (or species guild) could be used to identify areas where new habitat patches should be created, where existing habitat patches should be enlarged, or where habitat connectivity should be improved or restored. The Region 4 SEF report included an ancillary Mississippi Delta analysis where bottomland forest restoration was recommended to meet the habitat needs of migrating and resident neotropical forest birds (Carr et al. 2002). Ideally habitat and viability models could be used to identify areas where habitat or corridor restoration would facilitate the protection of viable populations (Carroll et al. 2003; Carroll et al. 2004).

Based on the existing Regional assessments and the discussion above species analysis options include (Table 31):

- 1) Identification of specific locations or general areas important for imperiled species and other species of conservation interest using Natural Heritage occurrence data.
- 2) Identification of other specific areas important for species using other available GIS data.
- 3) General identification of areas more likely to support species/wildlife habitat such as simple reclasses of land cover data.
- 4) Development of habitat maps using simplified query-based approaches or habitat quality index scores for various focal species or at least a few selected umbrella or indicator species.
- 5) Development of habitat maps using more formal statistical approaches such as multiple logistic regression.
- 6) Conducting representation analysis using efficiency algorithms with Natural Heritage species occurrence data.
- 6) Viability assessments using non-spatial, or, preferably, spatially explicit viability models at least for wide-ranging and other fragmentation-sensitive species.
- 7) Incorporate information on critical habitat for federally listed endangered and threatened species
- 8) Identification of areas important for species habitat restoration.
- 9) Use the results of existing habitat and viability assessments such as the Florida Fish and Wildlife Conservation Commission's focal species analyses or TNC ecoregional plans.
- 10) Identification of areas impacted by invasive species or other stressors relevant to the conservation of specific taxa.

4. Ecosystem processes and natural disturbance regimes

Although natural disturbance regimes are considered to be ecological processes in conservation biology, landscape ecology, and reserve design, the SAB Framework has a separate EEA for ecological processes and natural disturbance regimes. The SAB Framework does acknowledge this by considering both of these Attributes as "process" attributes. Regardless, these two reporting categories are not addressed by any of the EPA Regional assessment projects included in this report. Although very important for maintaining functional ecosystems and ecological integrity, it is difficult to collect data addressing ecosystem processes especially at regional scales. As defined by the SAB Framework, ecological processes include energy flows and material flows such as primary production and nutrient cycling. Although such attributes have been focal points of community and systems ecology for many years, data relevant to these reporting categories at regional scales are generally unavailable. The Region 5 assessment index based on temperature and precipitation can be considered the analysis that comes closest to addressing ecological processes such as primary production in current EPA Regional assessments. However, opportunities to address primary production in regional ecosystem assessments include using imagery-based "greenness" indices as an indicator of primary production and have been applied in some species habitat models as a surrogate for prey production (Crist and Cicone 1984; Mace et al. 1999; Carroll et al. 2002; Noss et al. 2002). In addition, new data have recently become available with calculations of gross and net primary productivity at a 1 kilometer resolution for the globe. This data can be used to determine areas with highest productivity and how

production has changed over time in particular areas (Running et al. 2004; <http://images.nts.g.umn.edu/index.php>).

The maintenance, restoration, or at least effective mimicry of natural disturbance regimes is a critical consideration in reserve design for biodiversity (Harris et al. 1996a; Poiani et al. 2000). However, identifying areas that are most likely to support functional disturbance regimes is also difficult. The two most common disturbance regimes that are most frequently discussed in reserve design are fire and flooding (or alterations in hydrology). In the Southeastern Coastal Plain, the interactions between fire and flooding are essential for maintaining various ecotonal natural communities and many species (Harris and Kangas 1979; Harris 1988; Harris et al. 1996a; Hootman et al. In Press). Other important natural disturbances include natural insect outbreaks, hurricanes and other storm events, drought, and landslides (Turner et al. 1995; Gordon et al. 1997). There are important interactions between human activity and various natural disturbances that can affect the frequency, extent, duration, and intensity of disturbances (which are the four SAB reporting categories for the Natural Disturbance Regime EAA). Because of the pervasiveness of human activity and alterations to land cover, hydrology, and even climate, the relationship between what can be considered “natural” disturbance regimes and current disturbance regimes is very complex (Forman 1995; Turner et al. 1995; Turner et al. 2002). However, especially for fire ecology, the extent, frequency, and intensity of fire in various landscapes and natural communities is at least fairly well known, and natural hydrological cycles in many watersheds are also known.

Options for addressing natural disturbance regimes in regional-scale assessments of critical ecosystems include:

- 1) Identifying areas large enough to support the “minimum dynamic area” for a particular landscape or region (Pickett and Thompson 1978; Baker 1992). Simply put, this means knowing at least the extent and frequency of a natural disturbance regime and then identifying a large enough area to maintain all natural community types and seral stages of natural communities in a system where the natural disturbance (such as a let-burn policy) is allowed to operate or is mimicked through management such as prescribed fire. However, prescribed fire also would allow smaller management units to be managed with a “natural” disturbance regime though they may not be large enough to support the natural minimum dynamic area.
- 2) Identifying areas that are free, or relatively free, of stressors that might hinder natural disturbance regimes. The simplest example of this is to identify riparian systems or watersheds that are least impacted by human activities, especially dams or other forms of impoundment and channelization/ditching. Region 5 included analyses using dam information, and their analyses could serve as a coarse surrogate for identifying watersheds with the potential to support more natural disturbance regimes.
- 3) Using greenness indices of satellite imagery to evaluate primary productivity.

5. Chemical and Physical Characteristics and Hydrology and Geomorphology

Within the context of regional-scale critical ecosystem assessments, the Chemical and Physical Characteristics EEA primarily addresses stressors related to the protection

of water, air, and potentially soil resources. The Hydrology and Geomorphology EEA addresses the protection of water resources and the ecological integrity of aquatic ecosystems. EPA Regional assessments address many of the water resource categories of analysis with work in Region 8 promising to add additional tools for assessing watershed integrity at regional scales. Important analytical topics include identifying watersheds that are most pristine or are important for providing drinking water and areas most important for protecting groundwater resources based on existing groundwater intake points, aquifer vulnerability to contamination, or other information.

One data issue for conducting analyses of watershed or aquatic system integrity is that water quality data are not available for all stream segments or water bodies. More comprehensive sampling data would be very helpful. Land cover based indicators for watershed integrity such as those being used or developed in the Region 8 assessment should also be useful for closing gaps in existing data. Another issue is the difficulty identifying all upstream segments from areas of interest (such as surface water intake points) to determine watershed areas of influence important for maintaining water quality for drinking water and other purposes. This issue may be resolved in new versions of hydrology data. The hydrologic derivative data base <http://edna.usgs.gov> will provide the following relevant coverages, which should be available in next two years:

- 1) Aspect
- 2) Contours
- 3) Flow Accumulation
- 4) Flow Direction
- 5) Reach Catchment Seedpoints
- 6) Reach Catchments
- 7) Shaded Relief
- 8) Sinks
- 9) Slope
- 10) Synthetic Streamlines

These data can also be used to conduct analysis of drainage areas upstream or downstream, flooding assessments, runoff analysis, etc. Furthermore, the EPA Source Water Assessment Project (SWAP) conducted by the National Risk Management Research Laboratory (described in Appendix B) may also be a useful data source for areas critical for protecting drinking water. Delineating protection areas for drinking water sources is a primary objective of SWAP, and the assessment includes descriptions of three case studies demonstrating the use of selected GIS-based software and hydrologic models to conduct hypothetical source water evaluations.

Storm protection and flood control are ecosystem services pertinent to the hydrology and geomorphology EEA and to identifying critical ecosystems. Floodplain and COBRA data from FEMA are the most relevant existing information, but floodplain data are not consistently available for all regions. New floodplain data created by the Federal Emergency Management Agency (FEMA) should provide improved and consistent data across the United States (http://www.fema.gov/fhm/mm_main.shtm). Consistent, high quality floodplain information is needed to determine area of functional floodplain for determining areas critical for maintaining natural flood control benefits.

Another important spatial tool for addressing water resources is the Automated Geospatial Watershed Assessment (AGWA) tool. AGWA is an extension for ESRI's ArcView 3.2 that uses readily available GIS data sets obtained through the Internet to parameterize and run two spatially distributed watershed runoff and erosion models, the Soil Water Assessment Tool (SWAT), and the Kinematic Runoff and Erosion Model (KINEROS). AGWA is designed to evaluate likely out-comes of management scenarios and rank different areas in a watershed in terms of likely consequences to change. It also can perform watershed analyses over large areas such as entire basins, making it ideal for regional-scale ecosystem assessments using watersheds as a unit of investigation. Model results are displayed in tabular format allowing managers to identify critical areas needing management activities and to anticipate sensitive and critical ecosystem areas for planning allowances. AGWA provides qualitative estimates of water runoff and erosion for a watershed, and has been tested in geographically diverse watersheds across the continental United States. The AGWA tool can use many readily available GIS data layers (coverages, shapefiles, and grids) from the Internet that are easily input into ArcView. Descriptions of AGWA, SWAT, and KINEROS are included in Appendix B. An additional tool that may be useful in critical ecosystem assessments is the Long-Term Hydrologic Impact Assessment tool (L-THIA), which can be used to model run off, recharge, and non-point source pollution using available land use, soils, and precipitation data (www.ecn.purdue.edu/runoff/).

Improvement and protection of water resources and related hydrological ecosystem services through riparian restoration should also be considered in regional-scale assessments of critical ecosystems. A spatial decision support tool for identifying priority wetland forest restoration areas in the Mississippi Delta, Eco-Assessor, is included in Appendix B. This tool includes consideration of wetland restorability, habitat, water quality, and hydrology to identify where wetland restoration would be most feasible and provide the greatest benefits.

Air pollution/air quality is an important issue for ecosystem integrity including ozone pollution, acid rain, mercury contamination, and climate change. However, most of these impacts are regional to global in scale and cannot necessarily be used to differentiate between areas within a regional-scale assessment of critical ecosystems. There are potential exceptions. Region 5 was able to use air quality data (OPPT air risk model) to identify areas that exceed emission thresholds for a variety of airborne pollutants. Assessment of potential for acidic and mercury deposition is an important gap in existing Regional projects. Such data are available from the National Air Deposition Network (<http://nadp.sws.uiuc.edu/>).

The identification of areas that could be important for carbon sequestration is another relevant issue. Although this is not addressed in any of the Regional assessments, there are other projects that appear to be developing assessment techniques for carbon sequestration that may be relevant to future Regional assessments. We include descriptions of several spatially explicit carbon sequestration potential projects in Appendix B.

Models assessing impacts of climate change are also potentially relevant to identification of critical ecosystems. Areas of critical concern could include areas most likely to be affected by sea level rise, precipitation, or potentially temperature changes.

Landscape connectivity is also important to allow species to respond to climate change, especially areas with high elevational diversity.

Based on existing Regional projects and other information, regional-scale assessments of critical ecosystems addressing chemical and physical characteristics, hydrology, and geomorphology could include:

- 1) Identifying basins with high water quality using BASINS and STORET data.
- 2) Using land cover data to make predictions regarding nutrient loading in watersheds.
- 3) Assessing/predicting relationships between various stressors and the ecological (or biotic) integrity of aquatic ecosystems.
- 4) Identification of areas important for protecting aquifers or aquifer recharge.
- 5) Identifying buffers for important surface waters/surface water intake points or assessing distance from all surface waters.
- 6) Identifying areas with more surface water bodies.
- 7) Identifying wetlands and floodplains, especially those most important for maintaining water quality or storing floodwaters.
- 8) Identifying areas/watersheds impacted by dams or channelization/ditching.
- 9) Identifying watersheds affected by toxic releases using TRI data.
- 10) Identifying areas with forest cover and high densities of stream start reaches.
- 11) Identifying areas important for restoring ecosystem services.
- 12) Identifying areas impacted/not impacted by acidic or mercury deposition.
- 13) Identifying areas important for carbon sequestration.
- 14) Assessing impacts of climate change and identifying areas most important for maintaining ecosystem integrity during climate change.

6. Development of criteria and sensitivity analysis in Regional critical ecosystem assessments

Finally, we recommend developing discussions and possibly a workgroup among EPA Regions and other relevant EPA organizations for incorporating review of criteria for identifying critical ecosystems, thresholds for determining ecological significance, and developing feasible sensitivity analyses for regional-scale critical ecosystem assessments. This was one of the Science Advisory Board's (SAB) recommendations from their review of the Region 4 Southeastern Ecological Framework. The Region 5 Critical Ecosystem Assessment Model is currently being reviewed by SAB, and the Region 6 GIS Screening Tool is scheduled to be reviewed soon. Once completed, all of these reviews could serve as a collective basis for enhancing future critical ecosystem assessments.

Table 31. Relevant Regional Critical Ecosystem Assessment analyses and inclusion within existing Regional assessments¹

Analysis Type	Region 4	Region 5	Region 6	Region 7	Region 8
Landscapes					
Roadless Areas or Road Density	X	X	X	X	X
Identifying Areas with Lack of Stressors (Other Than Roads)	X	X	X		X
Identifying Areas of Protected Lands	X		X		
Identifying areas with high land cover or natural community diversity	X	X		X	
Identifying large, intact patches or areas	X	X	X	X	X
Assessing patch shape	X	X	X		
Assessing habitat fragmentation	X	X	X	X	X
Identifying interior habitat	X	X	X		
Identifying areas with habitat/natural community patches in close proximity				X	
Identifying areas important for maintaining or restoring landscape connectivity	X				
Natural Communities					
Identifying rare or imperiled natural communities using Natural Heritage data	X	X			
Identifying important matrix communities or ecoregion-specific “appropriate” land cover including use of potential natural vegetation		X			
Identifying important natural communities using representation or similar analyses					
Identifying important natural communities using other available GIS data	X	X	X	X	X
Species					
Identification of areas important for imperiled species and other focal species using Natural Heritage occurrence data	X	X	X	X	
Identification of other specific areas important for species using other available GIS data	X		X		X
General identification of areas more likely to support species/wildlife habitat such as simple reclasses of land cover data			X		
Development of habitat maps using simplified query-based approaches or habitat quality index scores for various focal species or one or more umbrella or indicator species	X				
Development of habitat maps using more formal statistical approaches					
Conducting representation analysis using efficiency algorithms with Natural Heritage species occurrence data.					
Viability assessments using non-spatial or spatially explicit viability models at least for wide-ranging and other fragmentation-sensitive species					

Table 31 Continued. Relevant Regional Critical Ecosystem Assessment analyses and inclusion within existing Regional assessments¹

Analysis Type	Region 4	Region 5	Region 6	Region 7	Region 8
Species					
Incorporate information on critical habitat for federally listed endangered and threatened species					
Identification of areas important for species habitat restoration	X			X	
Use the results of existing habitat and viability assessments such as the Florida Fish and Wildlife Conservation Commission's species analyses or TNC ecoregional plans	X				
Identification of areas impacted by invasive species or other stressors relevant to the conservation of specific taxa	X	X	X	X	X
Ecosystem Processes and Natural Disturbance Regimes					
Using greenness indices or new primary productivity data calculated from satellite imagery					
Identifying areas large enough to support "minimum dynamic areas"					
Identifying areas that are free, or relatively free, of stressors that might hinder natural disturbance regimes		X			
Chemical and Physical Characteristics, Hydrology, and Geomorphology					
Identifying basins with high water quality using BASINS and STORET data		X	X		
Using land cover data to make predictions regarding nutrient loading in watersheds					X
Assessing/predicting relationships between various stressors and the ecological (or biotic) integrity of aquatic ecosystems					X
Identification of areas important for protecting aquifers or aquifer recharge	X		X		
Identifying buffers for important surface waters/surface water intake points or assessing distance from all surface waters	X		X		
Identifying areas with more surface water			X		
Identifying wetlands and floodplains, especially those most important for maintaining water quality or storing floodwaters	X	X	X	X	
Identifying areas/watersheds impacted by dams or channelization/ditching		X	X		X

Table 31 Continued. Relevant Regional Critical Ecosystem Assessment analyses and inclusion within existing Regional assessments¹

Analysis Type	Region 4	Region 5	Region 6	Region 7	Region 8
Chemical and Physical Characteristics, Hydrology, and Geomorphology					
Identifying areas with forest cover and high densities of stream start reaches	X				
Identifying areas important for restoring ecosystem services					
Identifying areas impacted/not impacted by acidic or mercury deposition					
Identifying areas important for carbon sequestration					
Assessing impacts of climate change and identifying areas most important for maintaining ecosystem integrity during climate change					

¹The symbol “X” indicates the Regional project included analysis addressing the category. This table is intended to show what the Regional projects address regarding various critical ecosystem analyses to serve as an indicator of what could be done in future assessments. It must be noted that these projects were not all designed to specifically identify critical ecosystems are all aspects of critical ecosystems, and other aspects of critical ecosystem assessment may be addressed in other currently ongoing efforts within Regions. Therefore, gaps in the analyses included in this table do not indicate relative importance or quality of a project or represent all research efforts that may be ongoing with various Regions.

V. Recommendations

A. Improving data and analytical tools

- 1) Develop a schedule for production of NLCD that meets the needs of Regions for a timely land cover and land use dataset. The schedule for developing new version of NLCD should be: 1) acquire the imagery; 2) use existing technology to develop NLCD quickly so that classified data are as close to being concurrent with base imagery as possible; and 3) use intervening time between final product and next acquisition to do the research to make NLCD better, but to always be ready to develop the next version in a short time frame (such as less than two years).
- 2) Procure a national version of Natural Heritage species and natural community occurrence data from NatureServe. These data should include the occurrences at original resolution with proper provisions for protecting the source data from FIA requests. Some state Natural Heritage programs also have data on significant natural areas, which could be useful if obtained.
- 3) Procure GIS tools such as APACK and SITES (or other reserve efficiency or irreplaceability software) in all regions to augment existing tools such as ArcGIS and ATtILA. Develop user guides to tools that address how these tools can be used to conduct specific critical ecosystem analyses.
- 4) Develop an EPA GIS database and tool repository specifically for regional-scale identification of critical ecosystems for data and tools that are currently not readily accessible. Develop a resource guide for locating all other relevant GIS data and tools that are available on the internet. The repository should include copies of all relevant nationally available GIS data, copies of relevant software tools, and guides to methodologies for applying tools to conduct specific critical ecosystem analyses.

B. Develop partnerships within and outside EPA to improve and implement assessments

- 1) Work with EPA Office of Research and Development's (ORD) Regional Environmental Vulnerability Assessment (ReVA) program to share national and regional data sets on ecological indicators and other relevant GIS data or tools. ReVA's themes, 1) measuring and monitoring environmental condition; 2) diagnosing potential causes for impaired condition; 3) forecasting future environmental stressors and conditions; and 4) developing effective restoration and remediation activities, are all relevant to identifying critical ecosystems.
- 2) Consider developing a partnership with The Nature Conservancy to use ecoregional planning data, methods, or results in critical ecosystem assessments.
- 3) Work with the U.S. Geological Survey (USGS) to make various data available sooner for conducting critical ecosystem assessments including state and regional GAP analysis and enhanced hydrology data.
- 4) Consider partnerships with states to help develop and/or use state strategic wildlife conservation plans to enhance critical ecosystem assessments.
- 5) Develop discussions and possibly a workgroup among EPA Regions and other relevant EPA organizations for incorporating review of criteria for identifying critical ecosystems, thresholds for determining ecological significance, and developing feasible sensitivity analyses for regional-scale critical ecosystem assessments. This

was one of the Science Advisory Board's (SAB) recommendations from their review of the Region 4 Southeastern Ecological Framework. The Region 5 Critical Ecosystem Assessment Model is currently being reviewed by SAB, and the Region 6 GIS Screening Tool is scheduled to be reviewed soon. Once completed, all of these reviews could serve as a collective basis for enhancing future critical ecosystem assessments.

C. Enhancing landscape analyses in Regional critical ecosystem assessments

- 1) The landscape category of analysis is probably the best addressed in current Regional assessments. However, analyses that identify intact landscapes are very important and all Regional critical ecosystem assessments should incorporate relevant methodologies for doing so.
- 2) Develop an EPA National Landscape Ecology Workgroup, which is a suggestion born out of the EPA sessions at the United States chapters of the International Association of Landscape Ecology (USIALE) conference in Spring 2004 (personal communication, Luis Fernandez, EPA Region 6) would be a beneficial step in developing more sophisticated and consistent landscape assessment techniques.
- 3) Take advantage of existing data such as those on forest fragmentation (Riitters et al. 2002) in future Regional critical ecosystem assessments.
- 4) Functional landscape connectedness or connectivity at landscape scales is a critical property for maintaining ecological integrity. Analyses identifying opportunities to maintain, or restore, habitat connections between large areas of ecological significance should be assessed. At the landscape scale (versus connectivity analysis for particular species), focal areas for connectivity should be riparian corridors (which complements riparian, wetland, and hydrological considerations), ridgelines, opportunities to maintain or restore elevational gradients (to combat global climate change), and other rational opportunities to maximize connectivity and, therefore, minimize fragmentation.

D. Enhancing natural community analyses in Regional critical ecosystem assessments

- 1) Obtain natural community occurrence data from NatureServe to identify locations of rare natural communities.
- 2) Conduct representation/irreplaceability analysis of natural communities or natural land covers using one of the several software packages available. A currently ongoing irreplaceability analysis in Region 7 could be the basis for developing procedures for conducting such analyses in all Regions.
- 3) Increase the number of natural community/land cover types in the National Land Cover Data (NLCD) to enhance representation/irreplaceability analysis. Another option is to use the land cover data of regional (or possibly state) USGS GAP analyses.
- 4) Consider conducting potential natural vegetation analyses similar to those conducted in Region 5 to augment representation/irreplaceability analysis. Potential natural vegetation can be used to help set representation goals. For example, natural communities that used to be common but are now very rare and are also poorly represented in existing conservation areas should be the highest priority for protection

efforts. Potential natural vegetation can also be used to determine the “appropriateness” of land cover types within ecoregions.

E. Enhancing species analyses in Regional critical ecosystem assessments

- 1) Obtain natural community occurrence data from NatureServe to identify locations of imperiled species.
- 2) Develop habitat models at least for a few focal species including wide-ranging species or indicators of specific community or landscape types.
- 3) Where possible, develop spatially-explicit population models for wide-ranging species or other species sensitive to fragmentation at regional scales.
- 4) Where available, consider using the results of existing assessments such as TNC ecoregional plans or USGS GAP analyses to address habitat or viability assessments for specific species as an alternative.
- 5) Obtain or collect data, or develop predictive modeling, to identify areas impacted, or with high potential to be impacted, by invasive species.

F. Enhancing natural disturbance regime analyses in Regional critical ecosystem assessments

- 1) Consider developing analyses that identify areas most likely to maintain, or with the best potential for restoration of, natural disturbance regimes. The Nature Conservancy would likely be a useful partner since consideration of natural disturbances has been incorporated in at least some TNC ecoregional plans. The concept of “minimum dynamic area” should be used as a starting point.

G. Enhancing chemical and physical characteristics, hydrology, geomorphology, and additional stressor analyses in Regional critical ecosystem assessments

- 1) Work with appropriate EPA entities to develop watershed assessments to identify watersheds with the highest ecological integrity or that are most important for protecting drinking water or other water resources. Two scales of analysis are appropriate. First identify the most significant watersheds using appropriate scale HUC units. Second, areas within watersheds most important for protecting surface water quality should be identified. This work could include the use of pollution sources data, models predicting water quality based on land use data, and possibly source water assessments such as those from the EPA Source Water Assessment Project (SWAP).
- 2) Where applicable, analyses should be developed to identify where restoration of riparian areas, floodplains, wetlands, or other vegetation would benefit water quality, flood abatement, or other relevant ecosystem services.
- 3) Determine whether data on acidic and mercury deposition can be incorporated into Regional critical ecosystem assessment projects.
- 4) Determine whether results of carbon sequestration models can be incorporated into Regional critical ecosystem assessment projects.
- 5) Consider adding assessment of climate change impacts to identify additional stressors to ecological integrity and to identify areas most important for mitigating impacts to natural communities and species.

- 6) Monitor the work in development by the Science Advisory Board (SAB) Committee on Valuing the Protection of Ecological Systems and Services (C-VPESS) for recommendations on developing spatial assessments of ecosystem services (<http://yosemite.epa.gov/SAB/sabcvpess.nsf/Background?OpenView>).

VI. Conclusions

Regional-scale identification of the ecosystems most important for conserving ecosystem services, ecological integrity, and biodiversity (e.g., critical ecosystems) provides an important foundation for proactive and efficient environmental protection. Conservation science elucidates the need for regional-scale analysis and planning to determine how environmental features are integrated, to effectively prioritize conservation efforts, and to provide a rational framework for ecosystem monitoring, protection, and management. Therefore, the identification of critical ecosystems is an essential step in EPA's mission to safeguard the environment for present and future generations.

Geographic Information Systems (GIS) provide the primary tool for identifying critical ecosystems at regional-scales. Over the last two decades, the amount of available data, data quality, and analytical tools have increased rapidly to expand the use of GIS in environmental applications. EPA Regions have done a good job applying GIS to explore identification of critical ecosystems. Current data and tools have allowed various Regions to conduct large scale assessments of critical ecosystems that address most of the categories of analysis contained in the EPA Science Advisory Board's Framework for Assessing and Reporting on Ecological Condition (Young and Sanzone 2002). Therefore, existing EPA projects provide a strong foundation for the next generation of critical ecosystem assessments that should be conducted in all EPA Regions.

This report contains discussion and recommendations for enhancing future iterations of EPA Regional critical ecosystem assessments. As conservation science and GIS continue to develop rapidly, new data and tools are becoming available. Other federal and non-government organization are developing data and tools, or have conducted assessments that are very relevant to EPA efforts. EPA should develop partnerships with various organizations that have expertise in regional-scale ecological analysis including the U.S. Geological Survey and The Nature Conservancy. Specific higher priority recommendations for enhancing future Regional critical ecosystem assessments include:

- 1) Establish a schedule for development of future iterations of the National Land Cover Data (NLCD)
- 2) Increase the number of land cover classes in future iterations of NLCD
- 3) Work with NatureServe to obtain the national database of rare natural community and imperiled species data
- 4) Consider developing partnerships with The Nature Conservancy, U.S. Geological Survey, and the states to use ecoregional biodiversity data, state and regional GAP analysis, enhanced hydrology data, and state strategic wildlife conservation plan data in critical ecosystem assessments.

- 5) Conduct representation/irreplaceability analyses for natural communities or land cover types
- 6) Incorporate habitat modeling and viability assessments for selected focal species
- 7) Develop methodologies for identifying landscapes with the greatest potential to maintain or restore natural disturbance regimes
- 8) Develop watershed, riparian, and source water assessments to better identify critical areas for protecting water resources
- 9) Incorporate data or analyses that identify areas important for carbon sequestration and consider including assessments of climate change to identify additional stressors to ecological integrity and to identify areas important for mitigating impacts on natural communities and species
- 10) Develop discussions and possibly a workgroup among EPA Regions and other relevant EPA organizations for incorporating review of criteria for identifying critical ecosystems, thresholds for determining ecological significance, and developing feasible sensitivity analyses for regional-scale critical ecosystem assessments. Existing and scheduled Science Advisory Board reviews of the critical ecosystem assessment projects in Region 4, Region 5, and Region 6 could serve as a starting point for these discussions.
- 11) Develop an EPA repository for data that is not currently readily accessible and a resource guide for locating all other relevant GIS data and tools for conducting regional-scale critical ecosystem assessments that would include methodology guides for using data and spatial tools to address all categories of analysis.

The Regional projects reviewed here have set a high standard for conducting critical ecosystem assessments, and there are many commonalities among existing projects as well as a number of useful unique features that can be used to develop a core set of methodologies applicable to all Regions. This report also represents steps towards cooperation among all Regions to share data and methods for conducting critical ecosystem assessments. The recommendations provide a foundation for future Regional efforts to identify critical ecosystems, and the next challenge is to take existing methodologies combined with new data and tools to develop a common framework of data and methods that facilitates the identification of critical ecosystems in all EPA Regions. The identification of critical ecosystems in all EPA Regions will provide a coherent framework of protection and management priorities, and such a framework will allow EPA to target resources more efficiently and develop better policies and programs to effectively protect environmental quality.

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